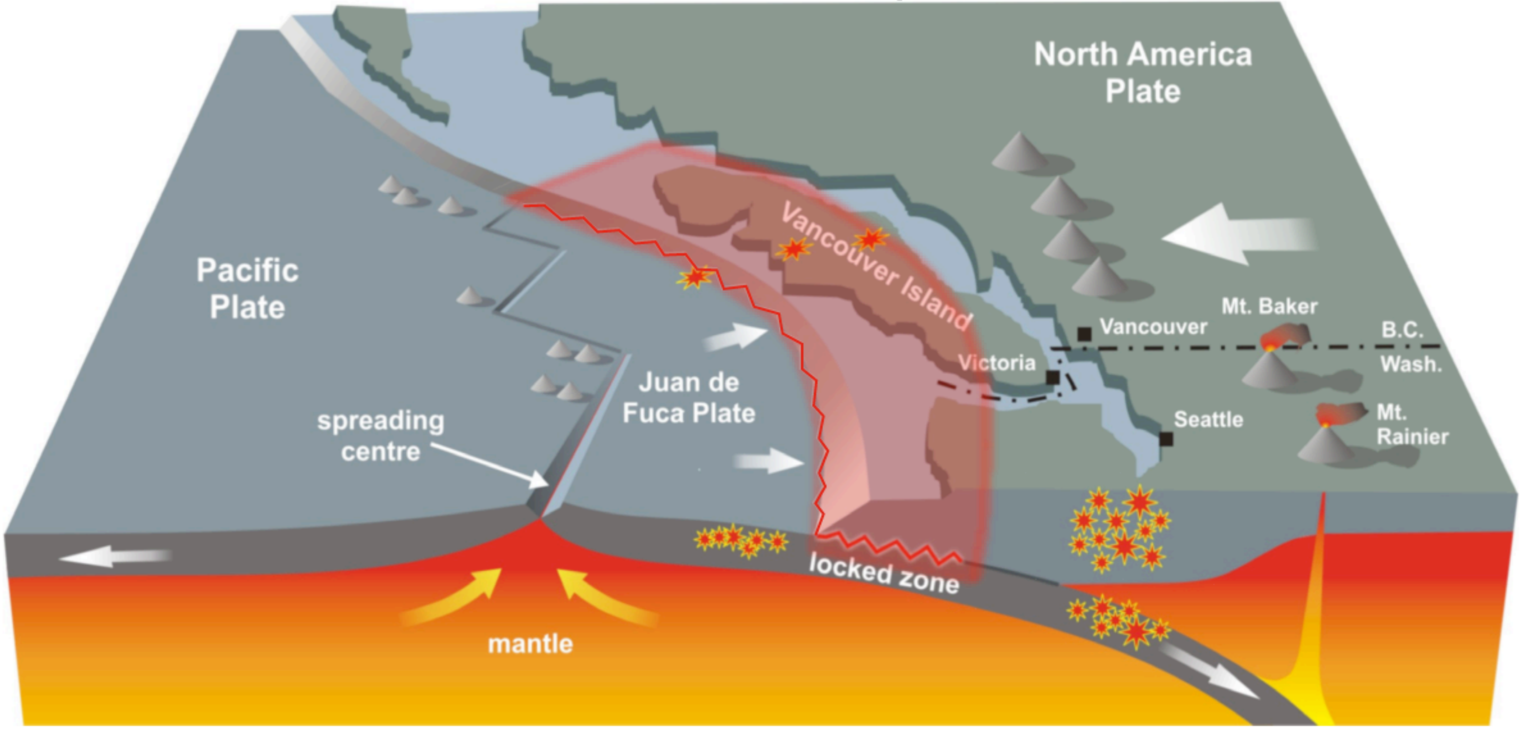
‘Megathrust’ Earthquakes in Cascadia & Japan

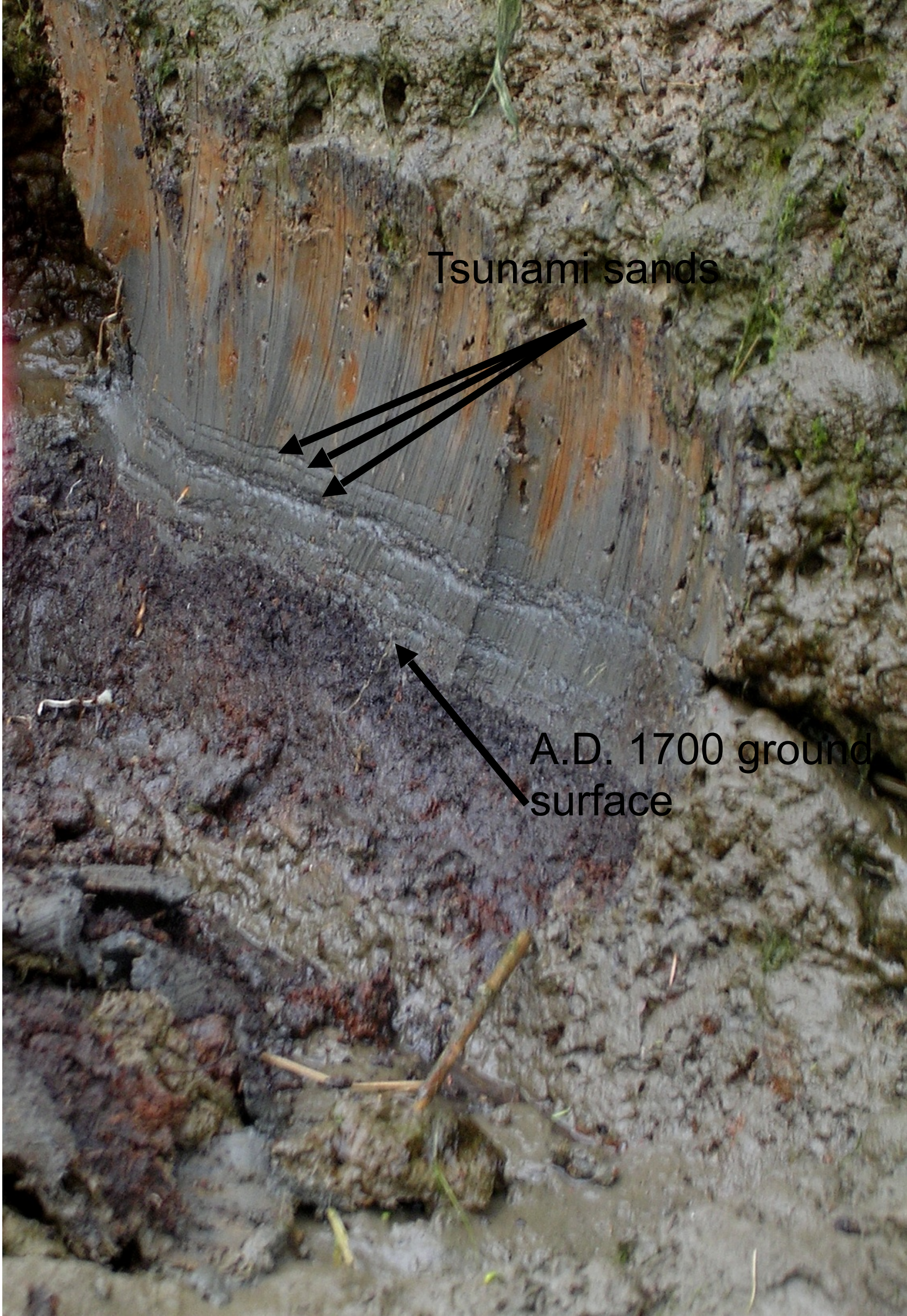
Cascadia Earthquakes



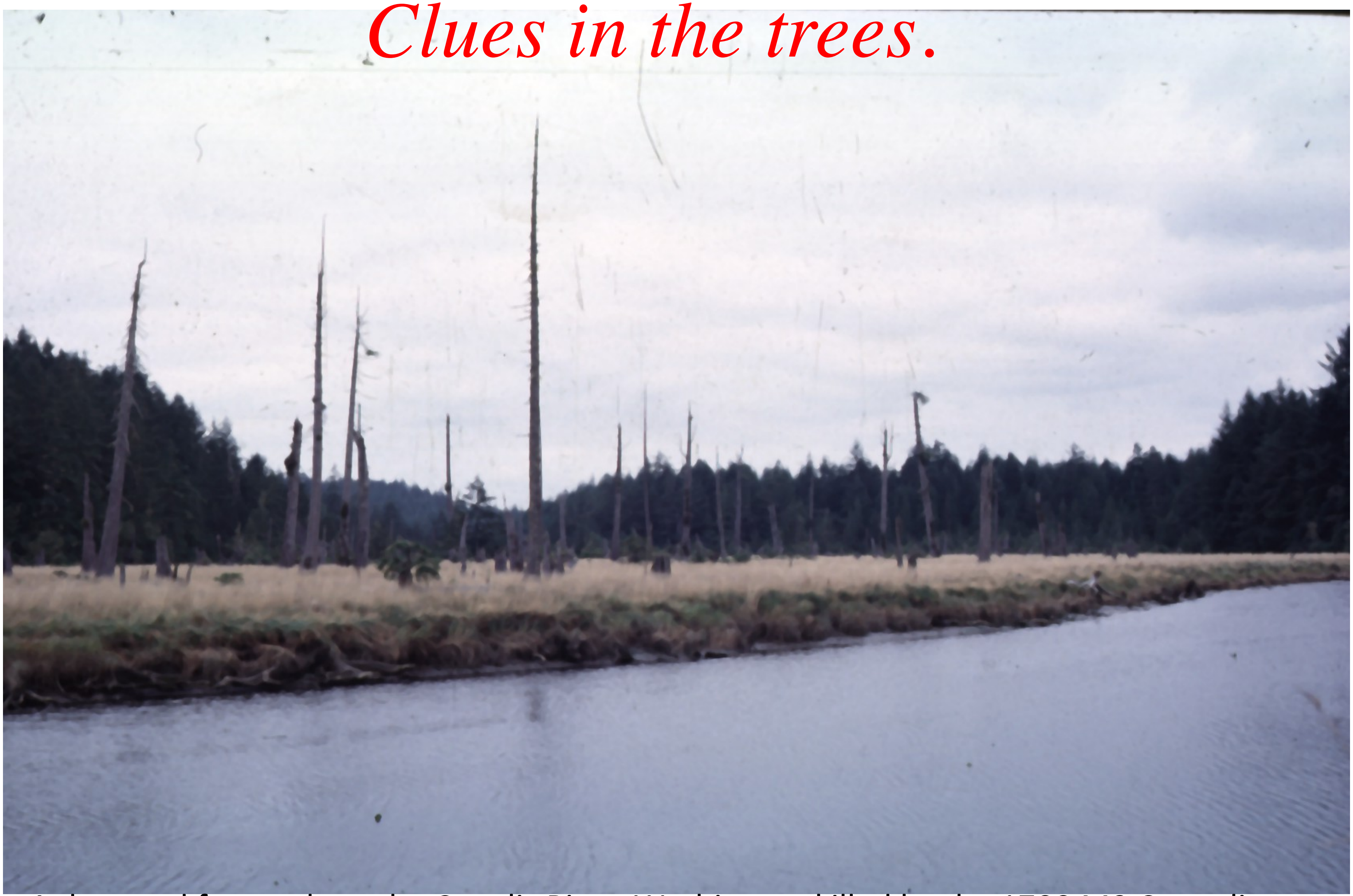
🟥 Interface (‘Megathrust’)

Clues in the dirt.

Right, subsided marsh along the Niawiakum River, southwest Washington. Below, note pitfalls of working in tidal marshes.

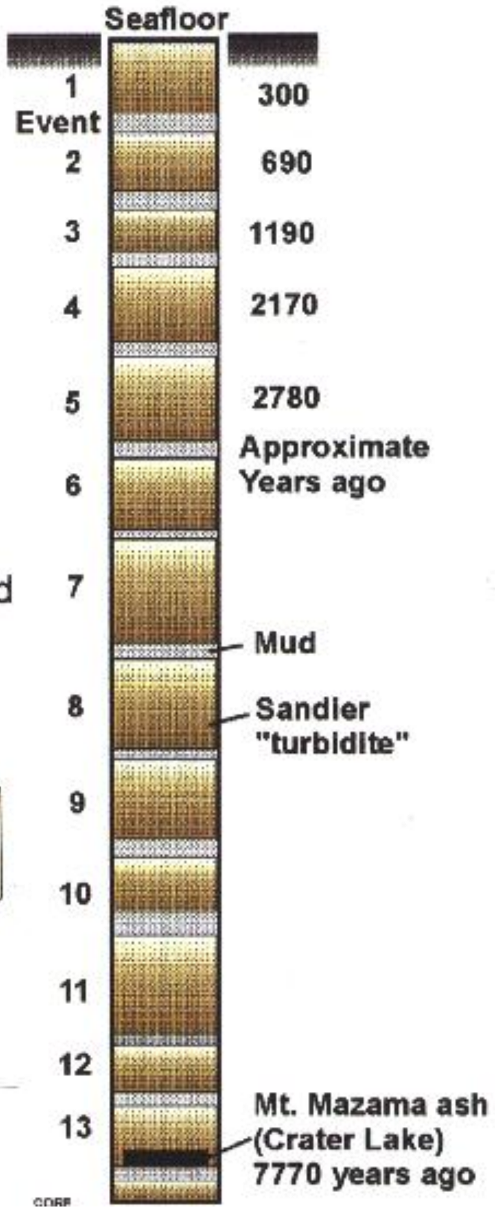


Clues in the trees.

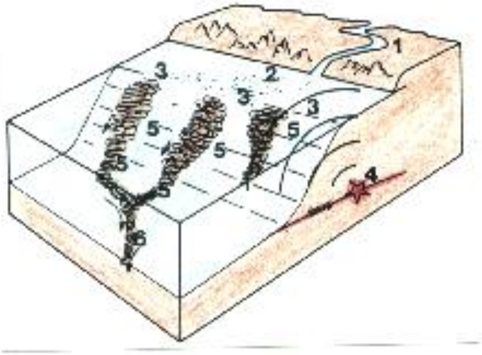


A drowned forest along the Copalis River, Washington killed by the 1700 M9 Cascadia earthquake.

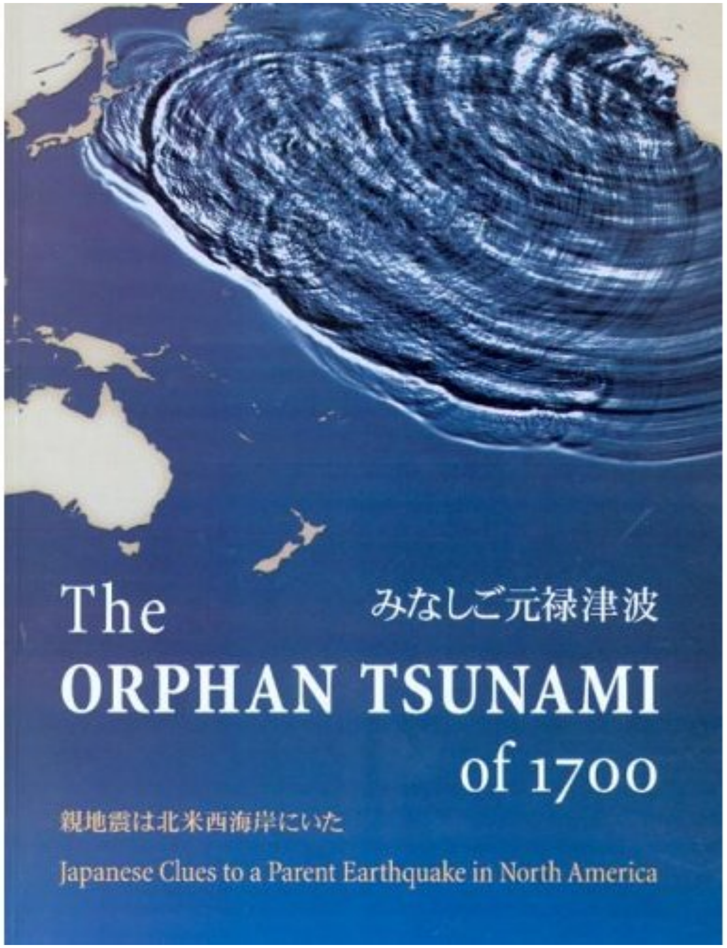
Clues Offshore.



Cascadia deep sea sediment core showing great earthquake-induced sedimentation events (After Adams, 1990)



The biggest clue was in Japan.



The

みなしご元禄津波

ORPHAN TSUNAMI

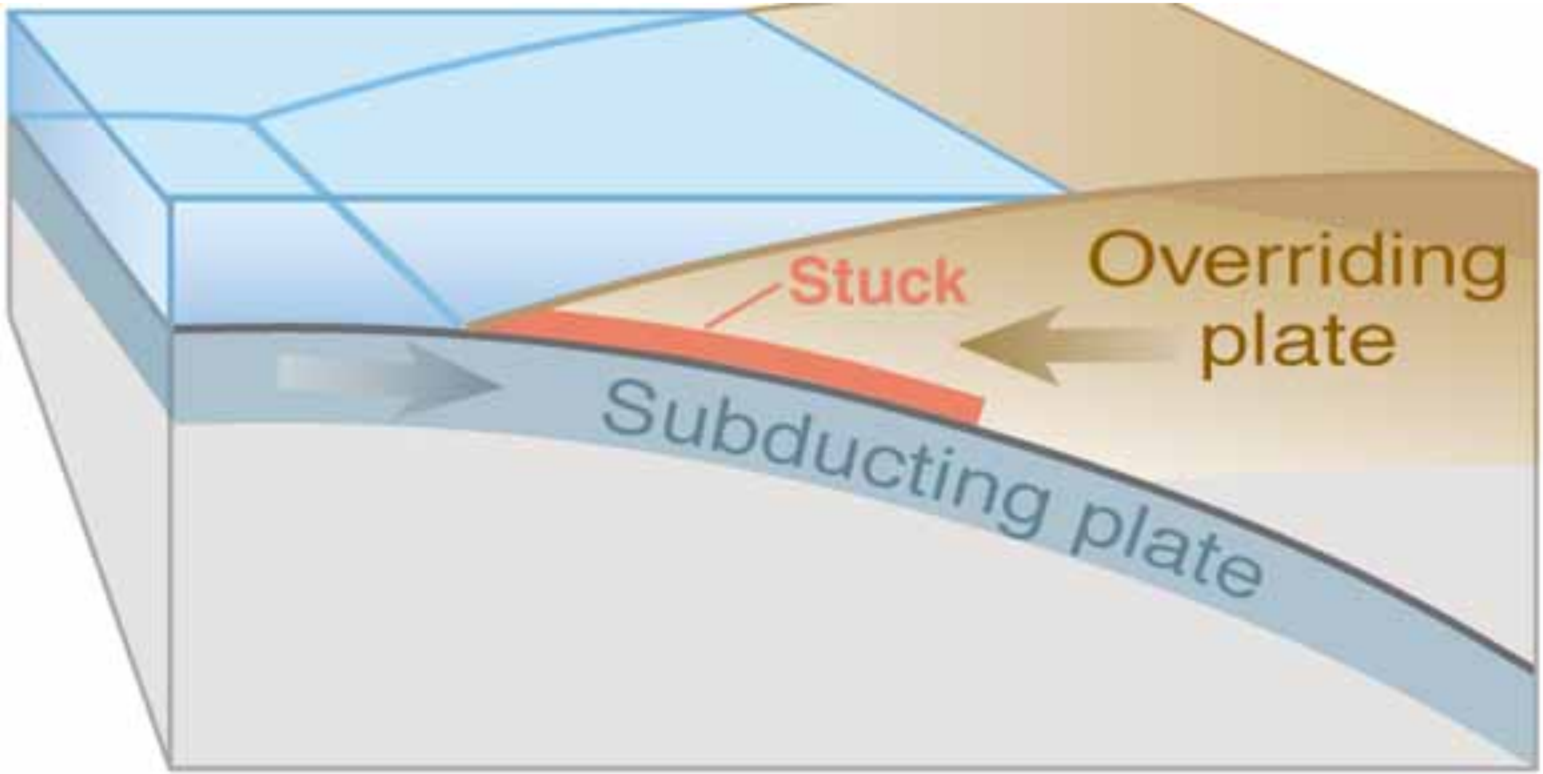
of 1700

親地震は北米西海岸にいた

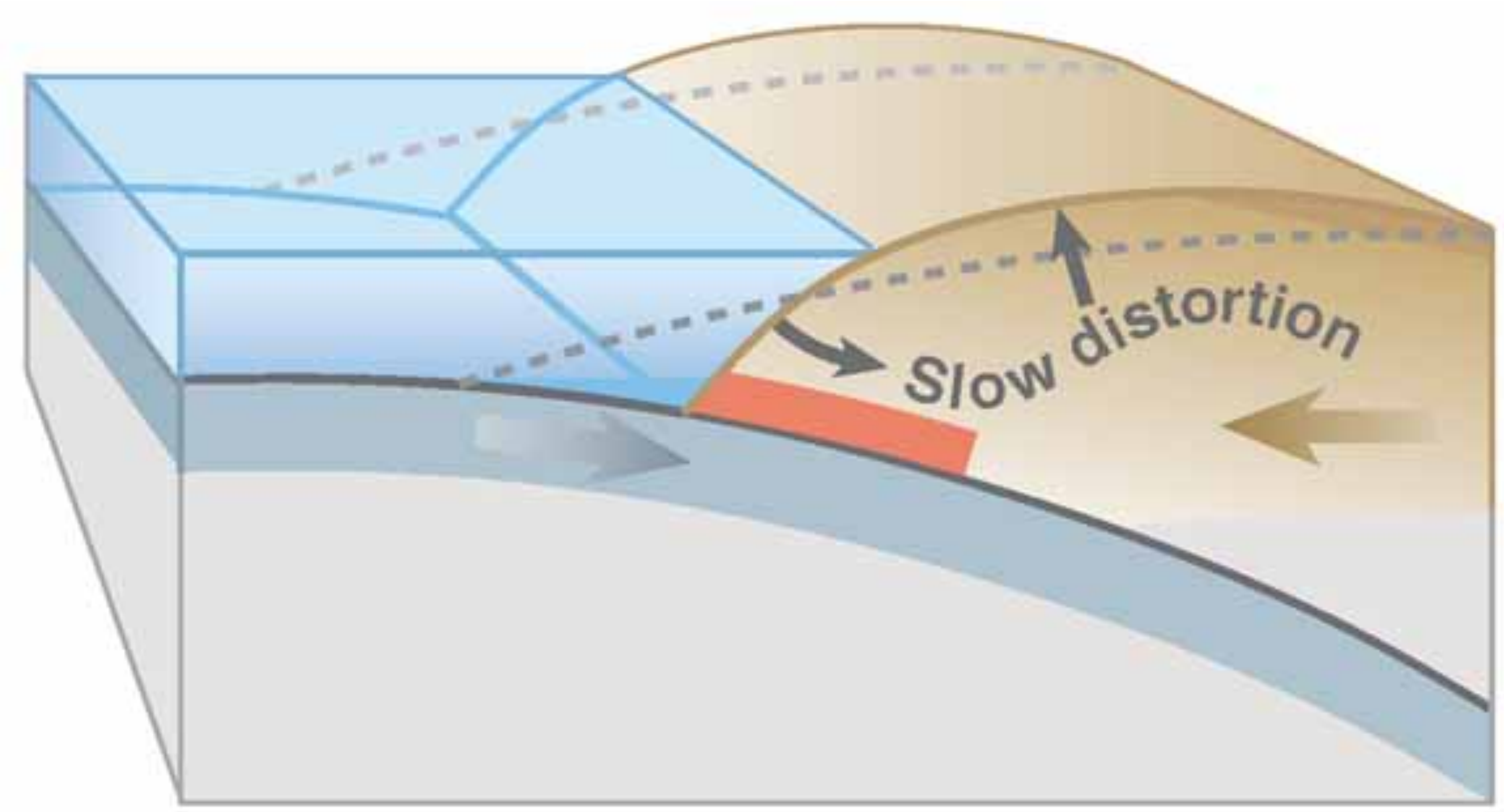
Japanese Clues to a Parent Earthquake in North America

by Brian Atwater et al., University of Washington Press

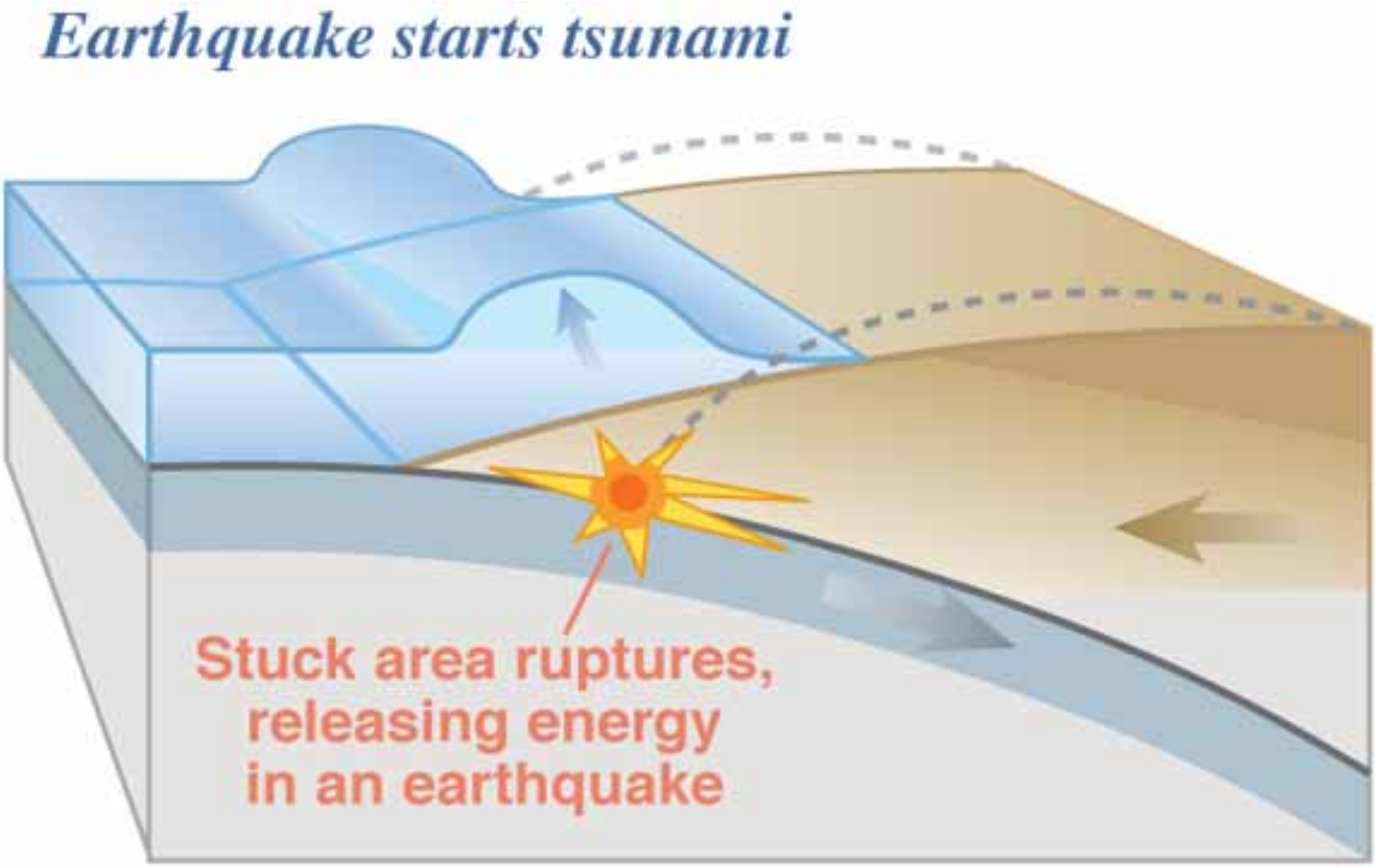
Earthquakes that vertically offset the seafloor generate tsunami.



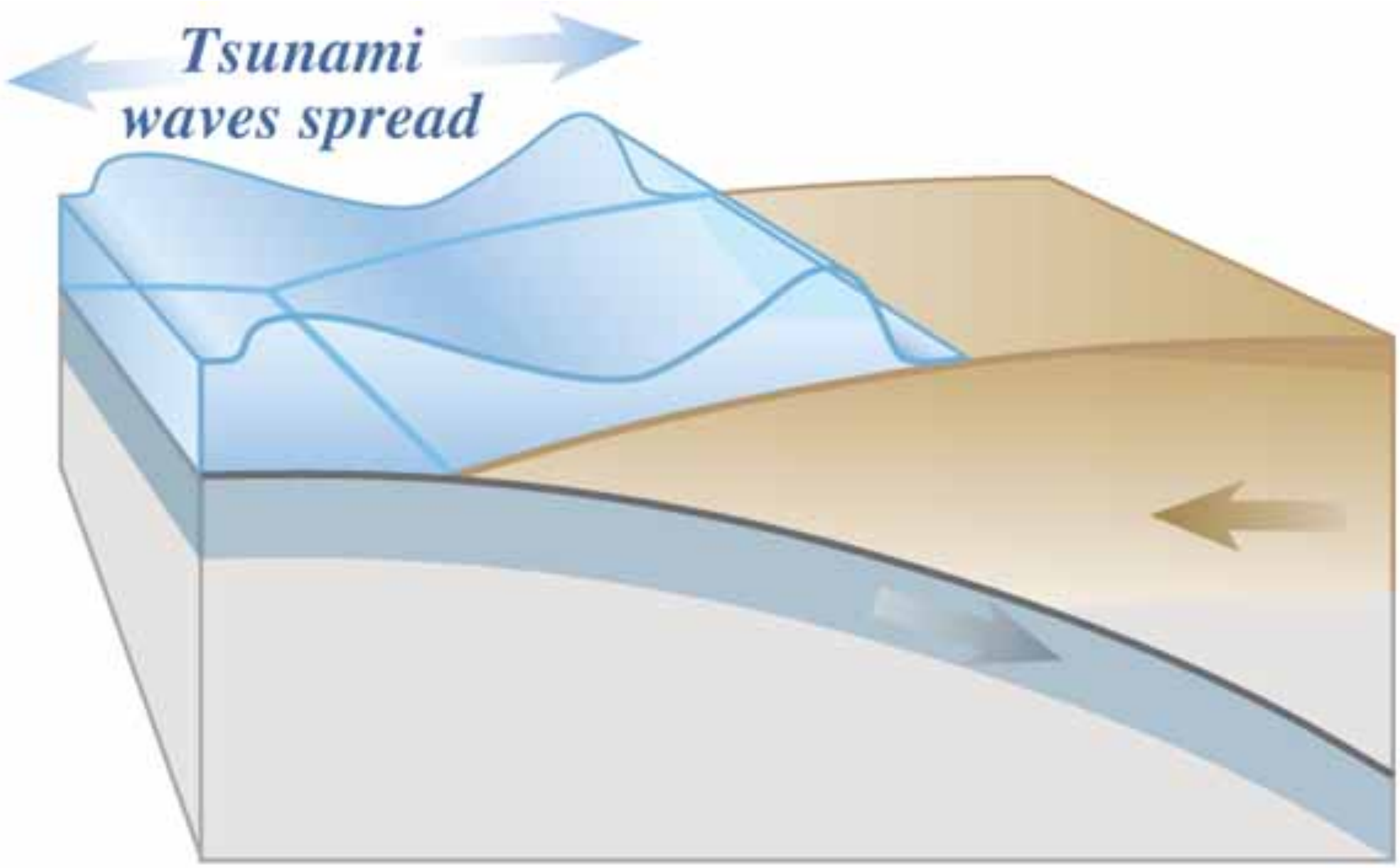
Stresses on the 'locked' part of the plate interface build for hundreds of years as the plates collide, but can't move.



The surface slowly deforms around the stuck fault.

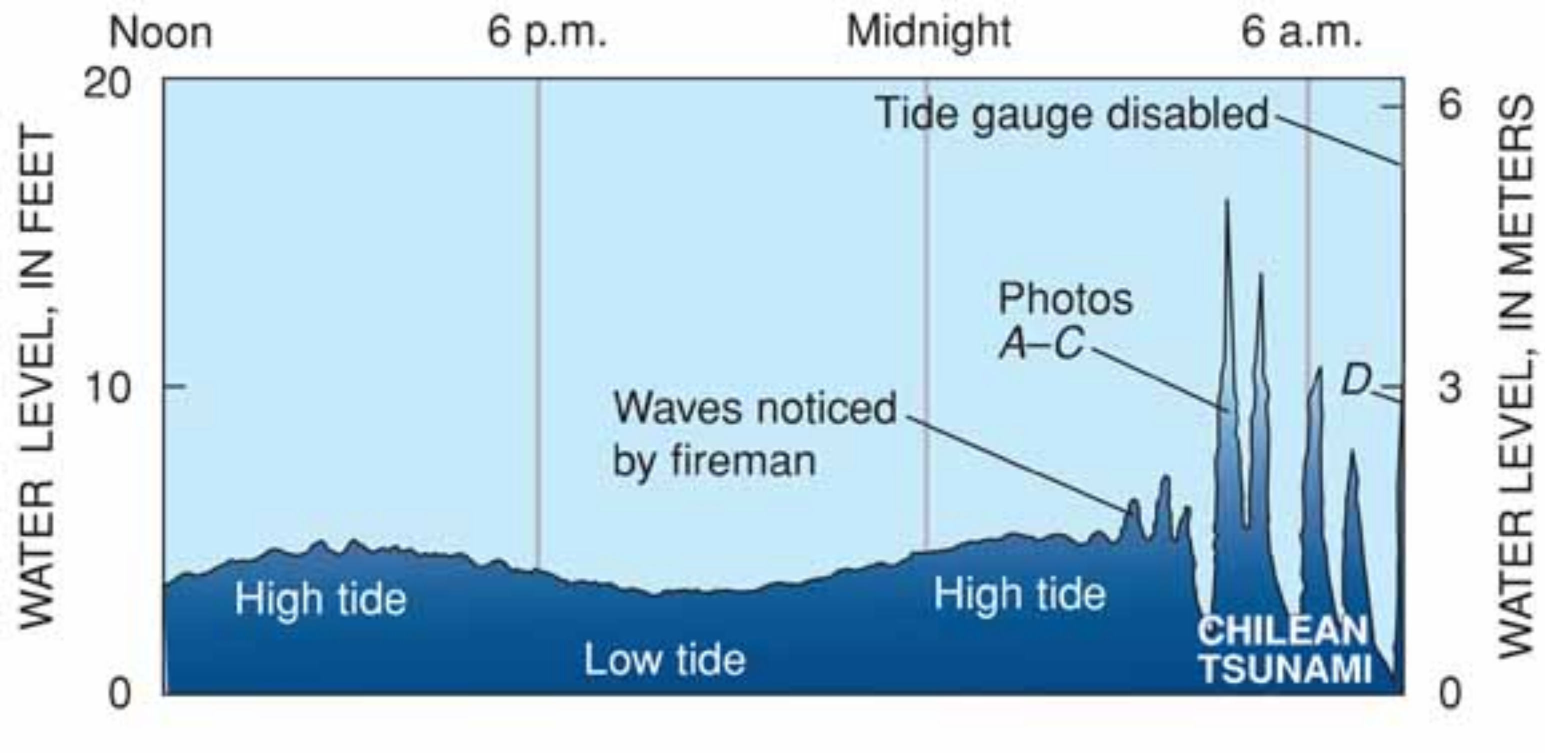

Earthquake starts tsunami
Stuck area ruptures, releasing energy in an earthquake

The stresses are released within minutes as the sides of the fault slip relative to each other, displacing by the amount that would have occurred if it hadn't been stuck.

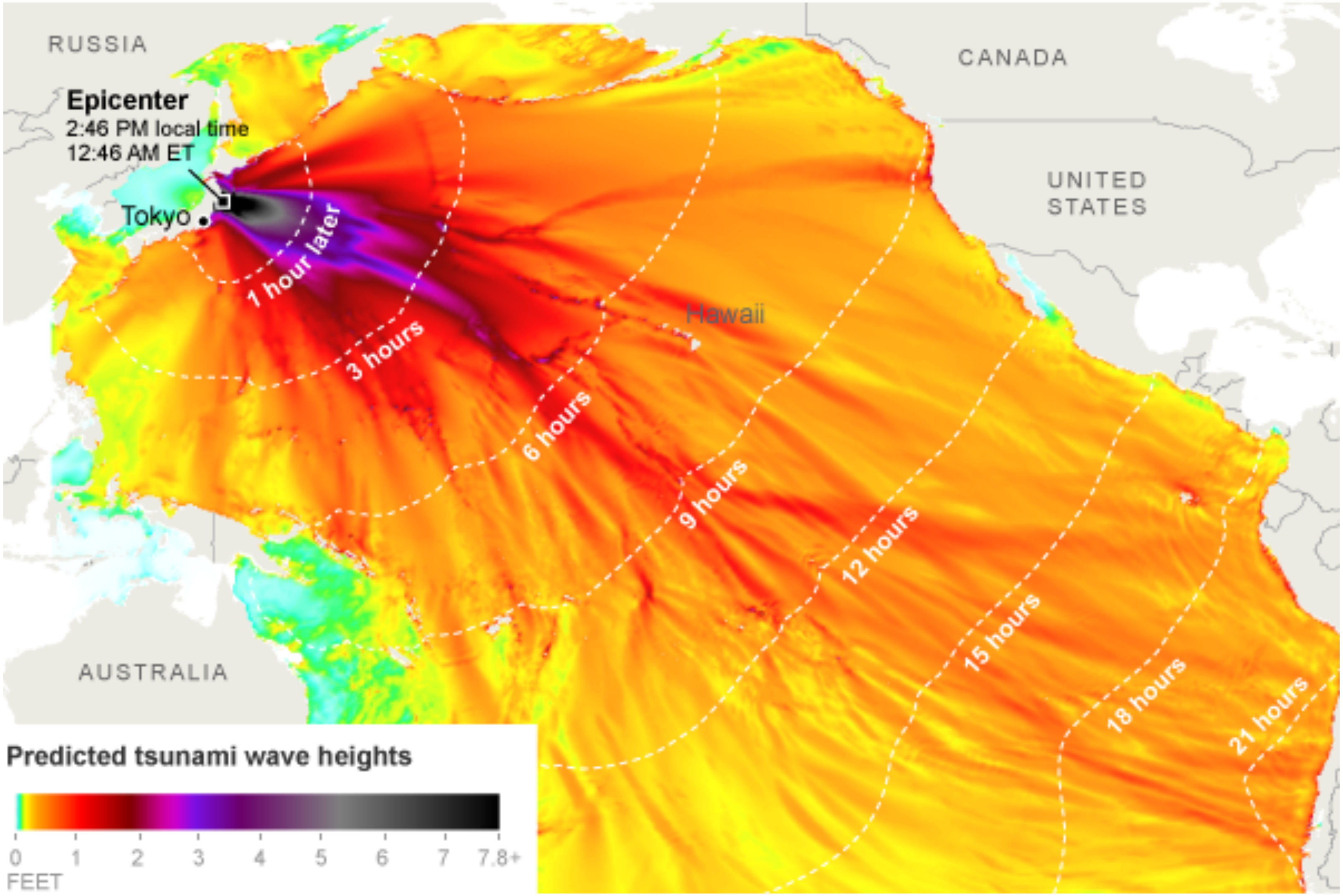


The sudden change in seafloor topography 'pushes' the water, creating a wave. A tsunami is born!

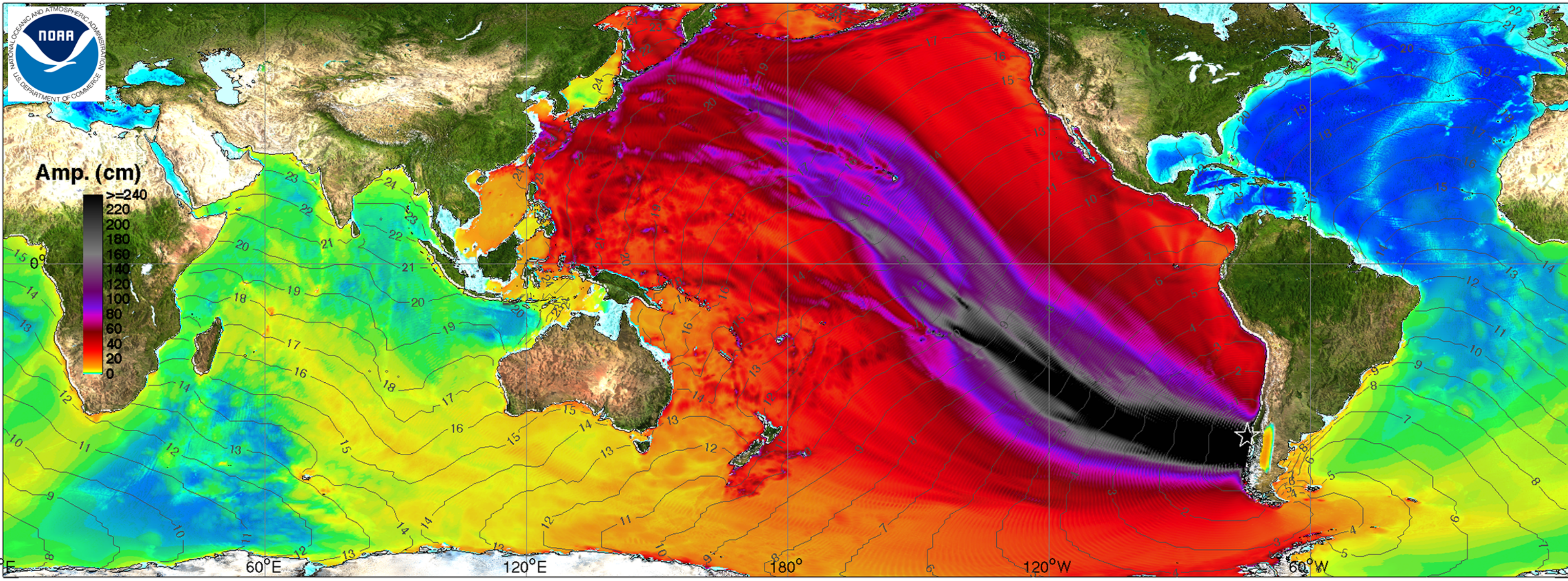
Not just 1 wave!



Tsunamis have global, but predictable impacts; M9.0 2011 Japan earthquake

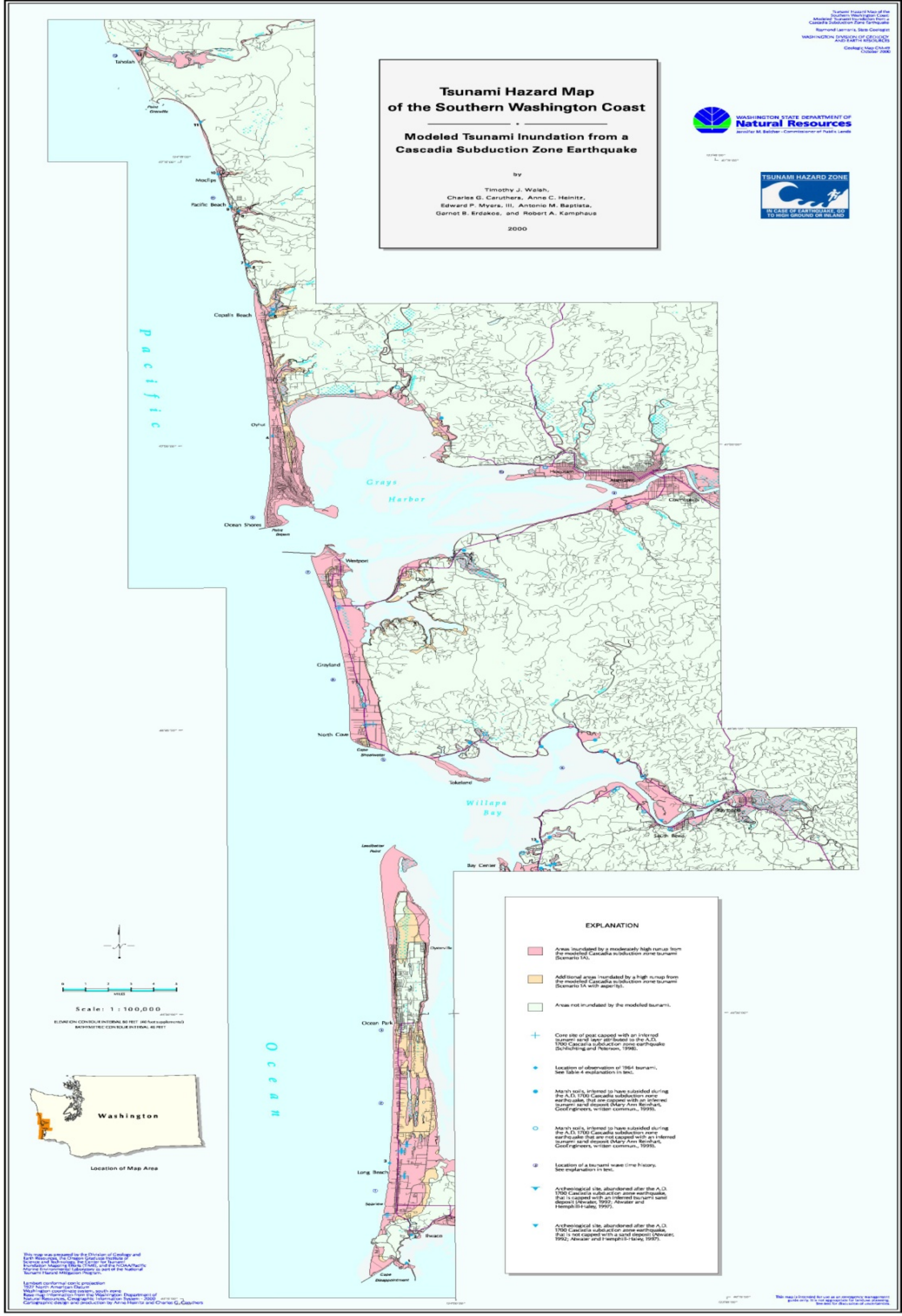


M9.5 1960 Chile earthquake

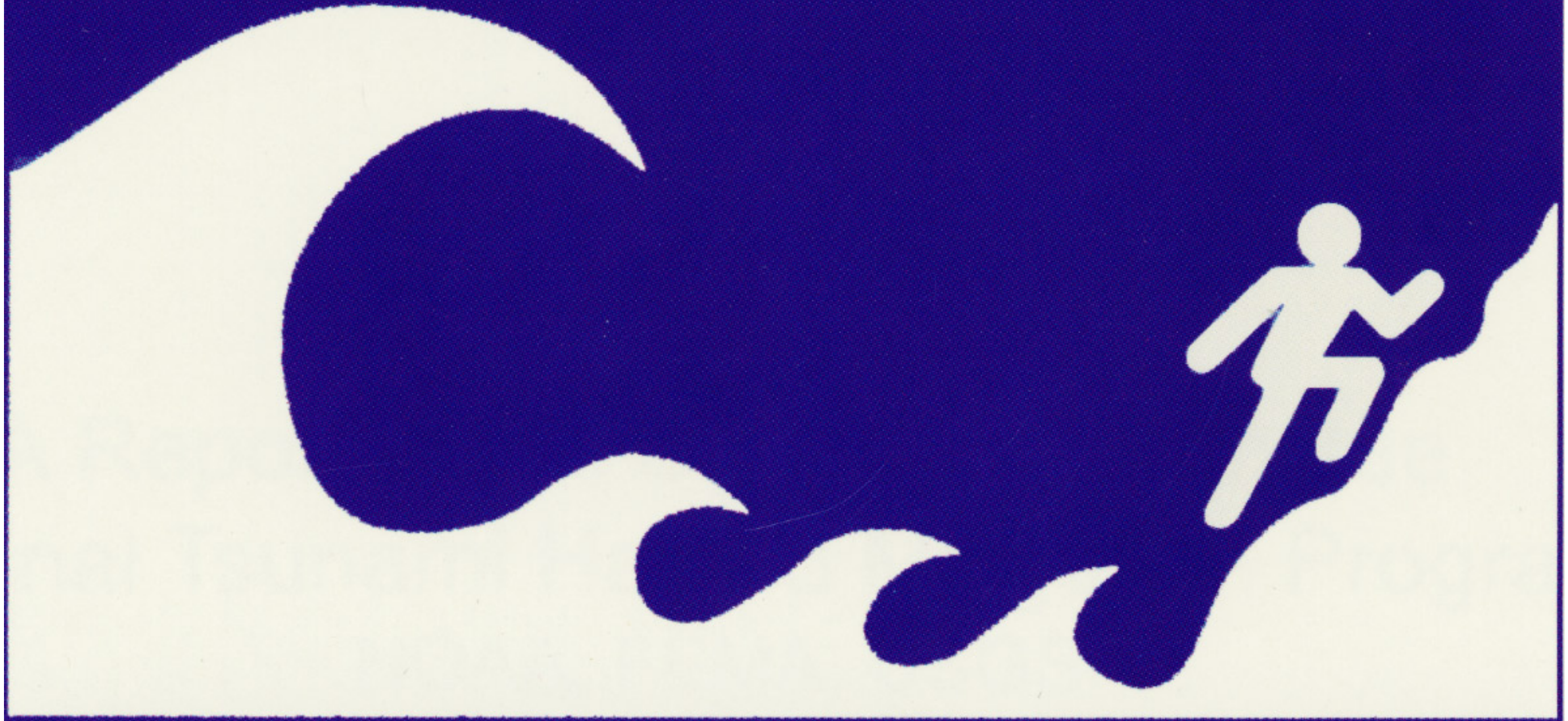

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Amp. (cm)
>=240
220
200
180
160
140
120
100
80
60
40
20
0
0°
60°E
120°E
180°
120°W
60°W

A tsunami generated by a Cascadia subduction zone earthquake will arrive in less than 45 minutes. For these events, as was the case in Banda Aceh, the earthquake must be the warning. Citizens must know where to evacuate from and where to evacuate to, and must do so quickly and on foot.

Note the long peninsulas or spits of low-lying ground. Ocean Shores peninsula is 7 miles long and Long Beach peninsula is 20 miles long with little or no high ground over those distances. For these areas, tsunami defenses are appropriate.


Tsunami Hazard Map
of the Southern Washington Coast
Modeled Tsunami Inundation from a
Cascadia Subduction Zone Earthquake
by
Timothy J. Walsh,
Charles G. Caruthers, Anne C. Heinitz,
Edward P. Myers, III, Antonio M. Baptista,
Garnet B. Erdakos, and Robert A. Kamphaus
2000
WASHINGTON STATE DEPARTMENT OF Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands
TSUNAMI HAZARD ZONE
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND
Raymond Lasmanis, State Geologist
WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
October 2000
Taholah
Moclips
Pacific Beach
Copalis Beach
Pacific
Grays Harbor
Ocean Shores
Westport
Grayland
North Cove
Tokeland
Willapa Bay
Bay Center
Ocean
Ocean Park
Long Beach
Ilwaco
Cape Disappointment
EXPLANATION
Scale 1:100,000
Washington
Location of Map Area

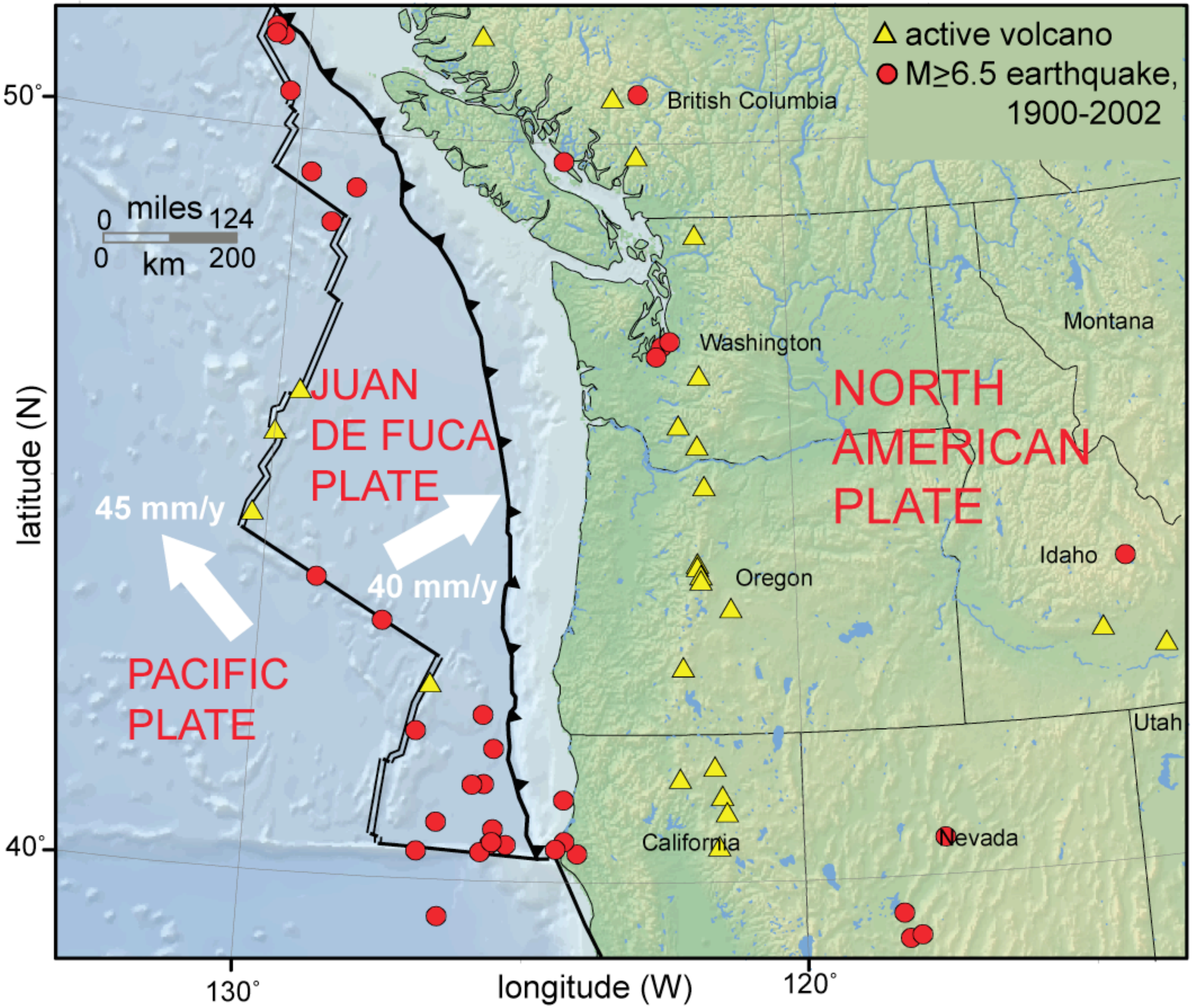
TSUNAMI HAZARD ZONE



IN CASE OF EARTHQUAKE, GO
TO HIGH GROUND OR INLAND

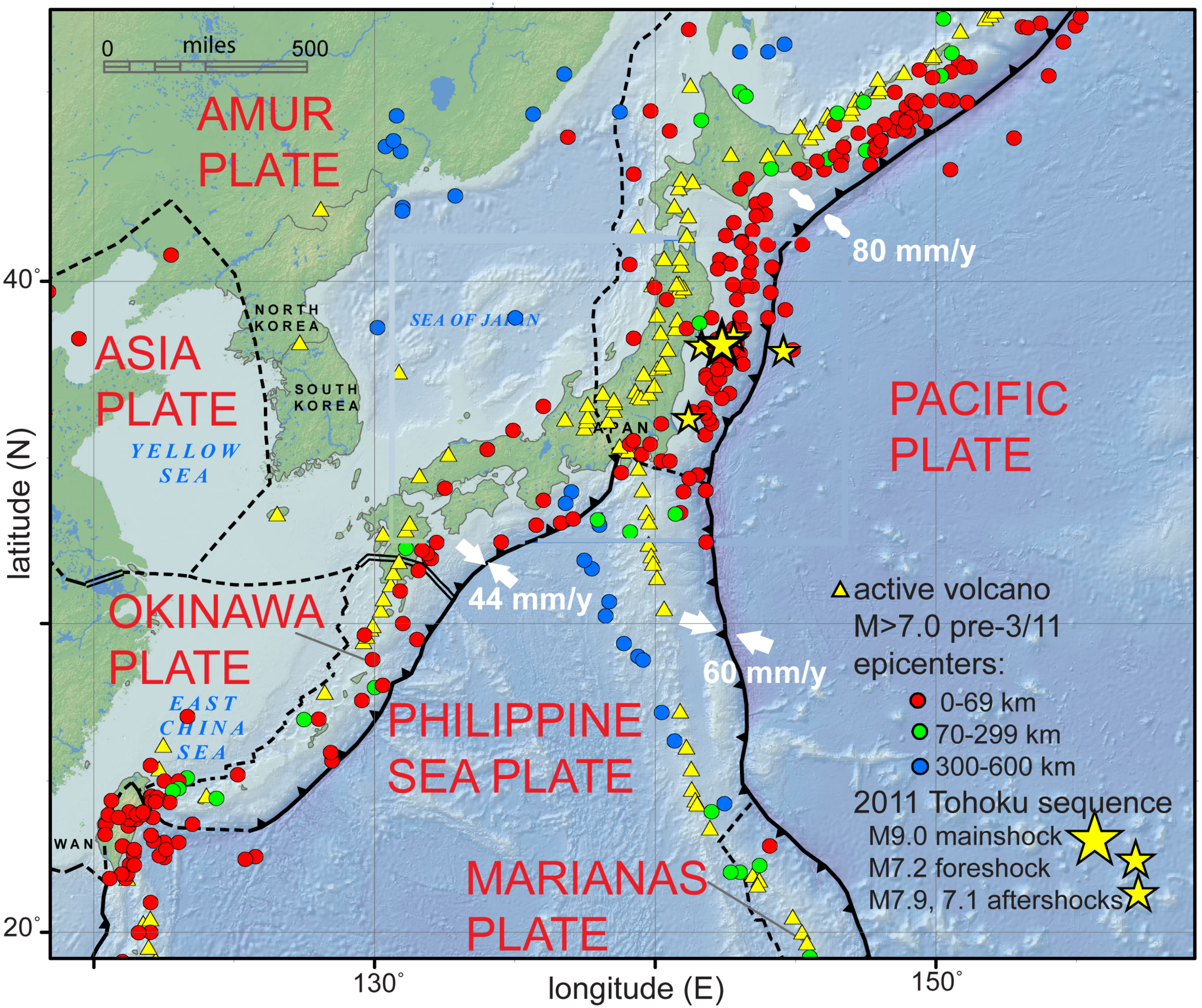
Japan & Cascadia share many similarities.

Cascadia - a usually silent ‘subduction zone’.



Japan & Cascadia share many similarities.

Japan - a complex system of subduction zones.



Consequences & Lessons

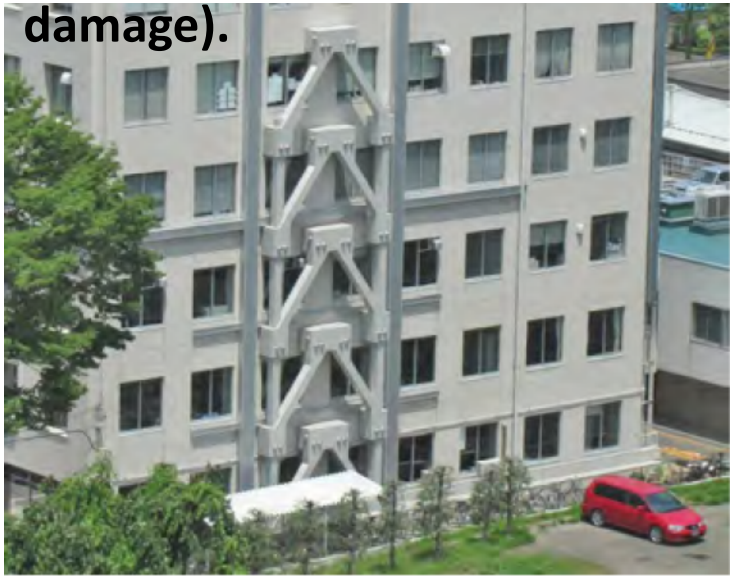
from the Structural Engineers Association of Washington

Very strong ground shaking (6 sites with >1.0g) lasted >3.0 minutes.

~160,000 people displaced, 12,000 missing, 15,217 confirmed dead - 90% by drowning.

$200- $300 (USD) billion in losses.

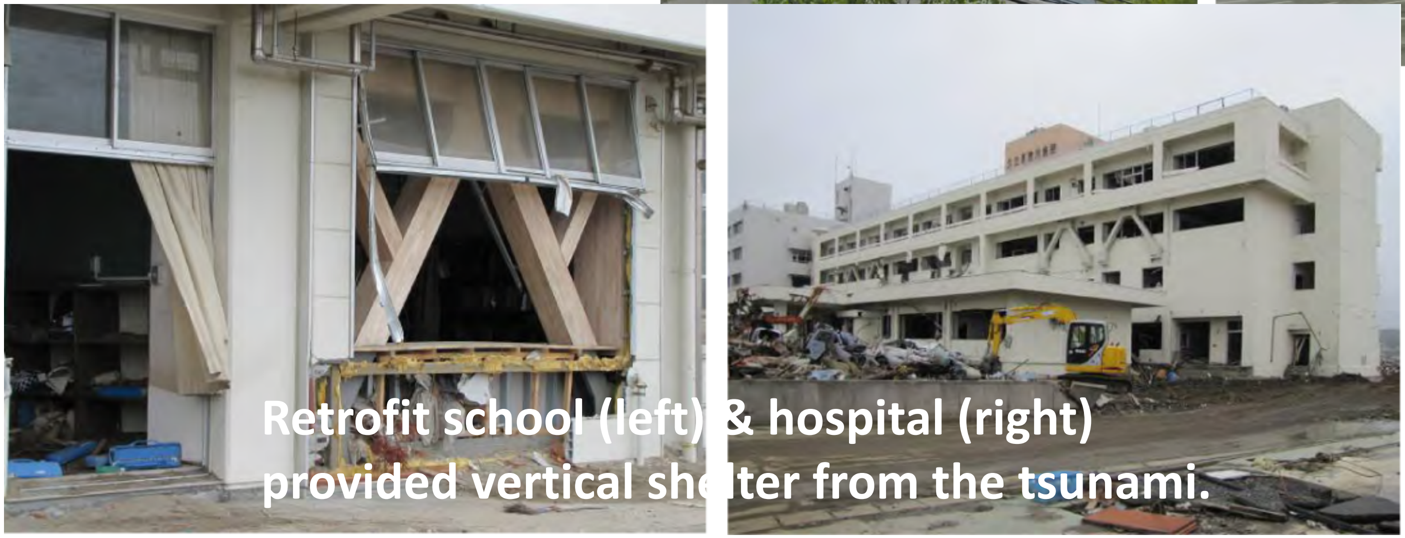
Seismic mitigation works! Most retrofitted buildings performed well.



Retrofit building in Sendai (no damage).

New high-rise building in Sendai; no structural but some equipment damage.

New high-rise in Tokyo swayed for >10 min; no structural damage.



Retrofit school (left) & hospital (right) provided vertical shelter from the tsunami.

Consequences & Lessons
from the Structural Engineers Association of Washington

The Japanese government invests in and encourages private sector support of earthquake and tsunami research and development, resulting in widespread application of earthquake protection technologies.

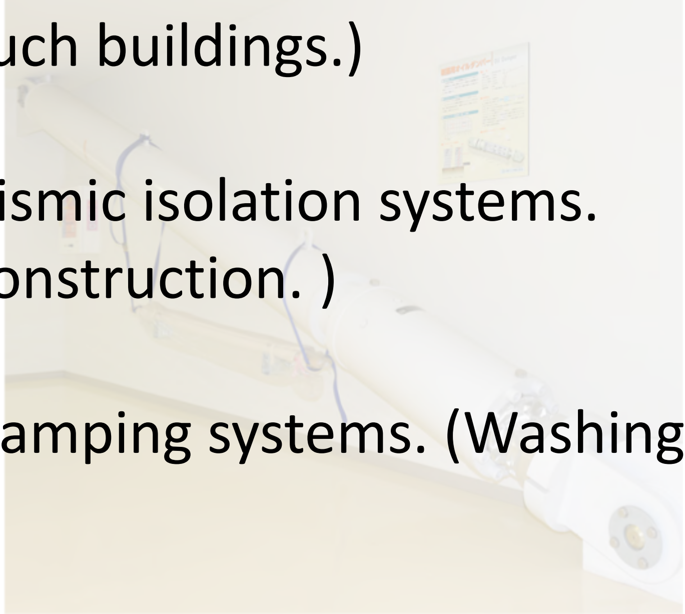
Rubber isolation bearing.

Hydraulic fluid viscous damper.

Consequences & Lessons
from the Structural Engineers Association of Washington

The Japanese government invests in and encourages private sector support of earthquake and tsunami research and development, resulting in widespread application of earthquake protection technologies.

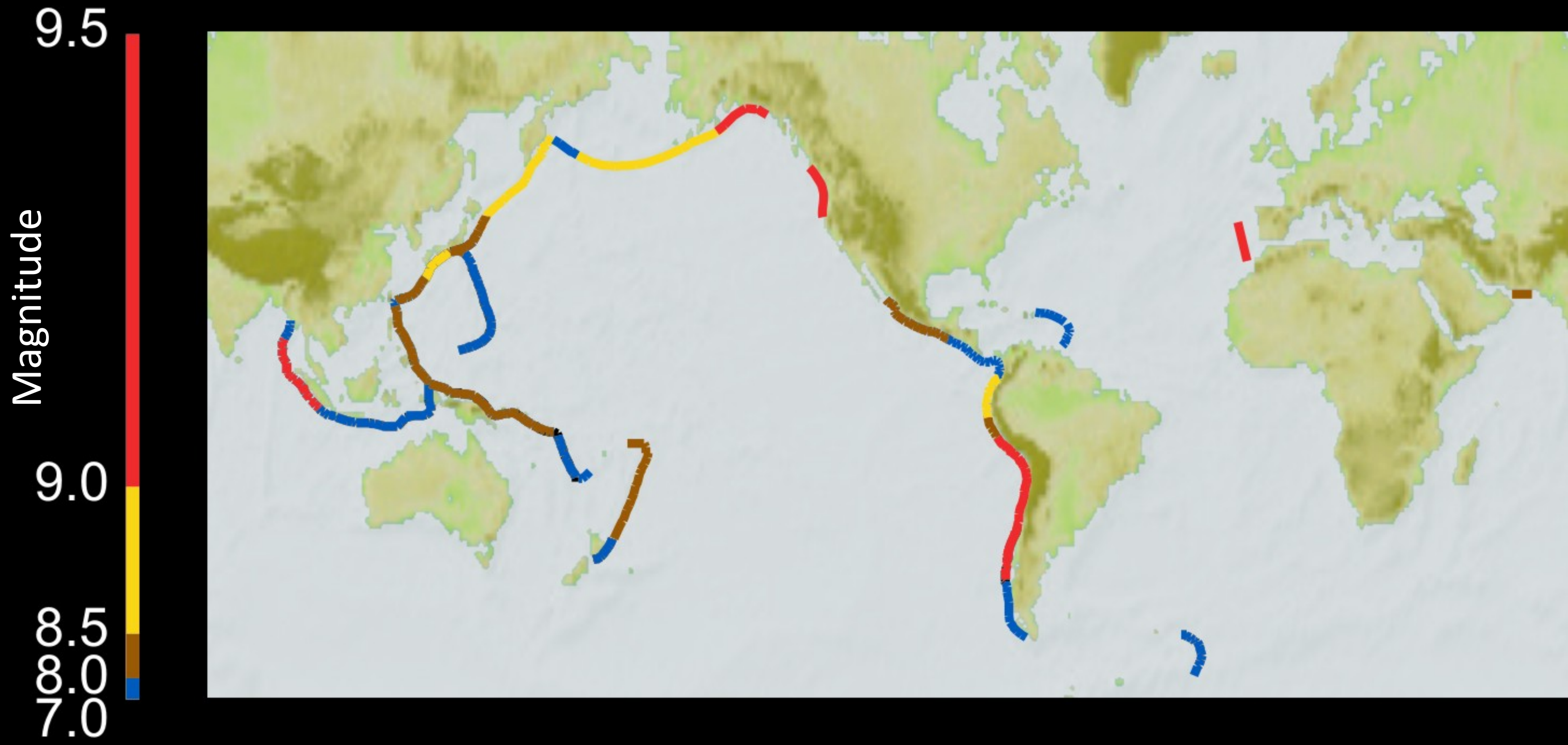
Japan has
>2,600 commercial and residential buildings with seismic isolation systems. (Washington State has 8 such buildings.)



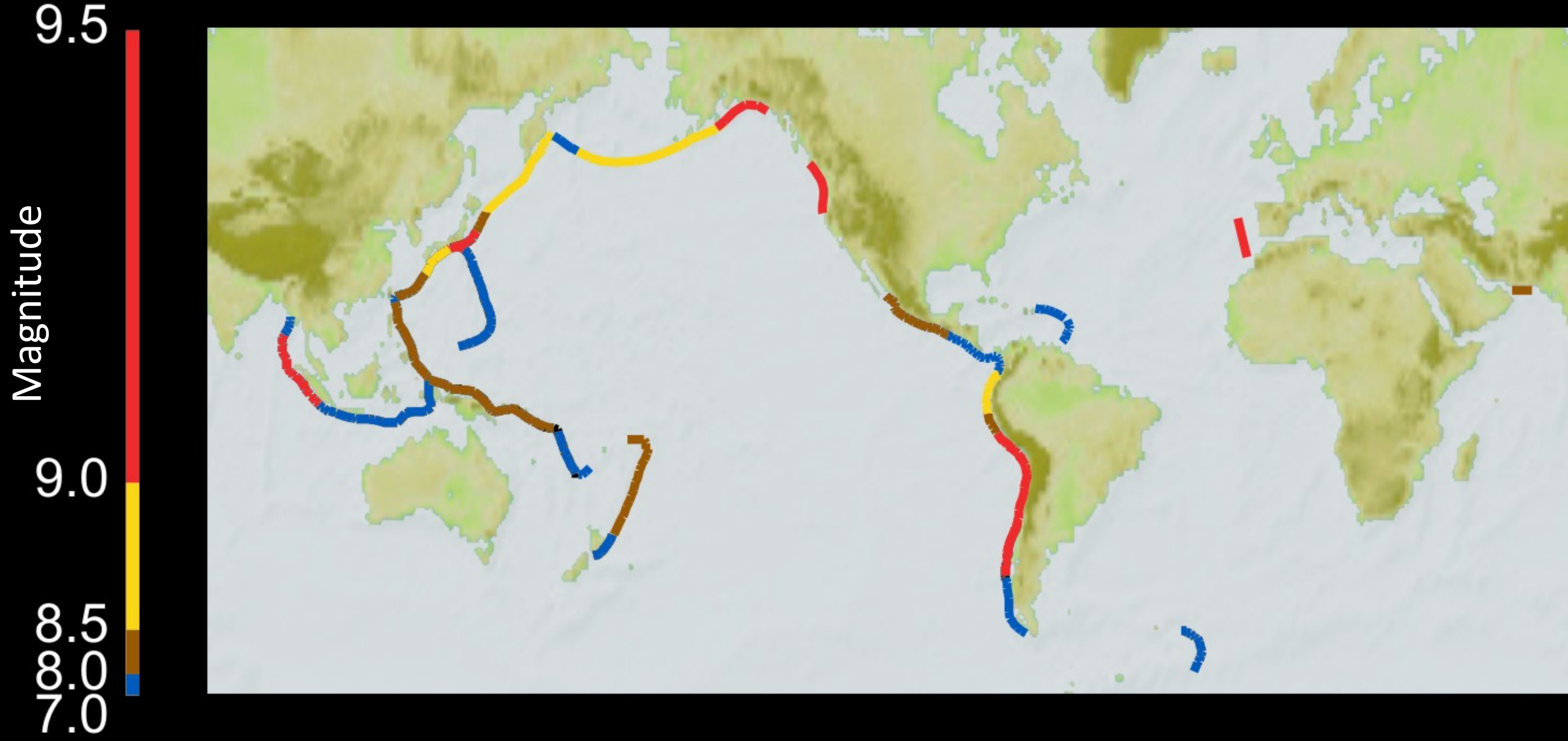
>3,800 single-family homes with seismic isolation systems. (Washington State has one under construction.)

>1,000 buildings with earthquake damping systems. (Washington State has 10.)

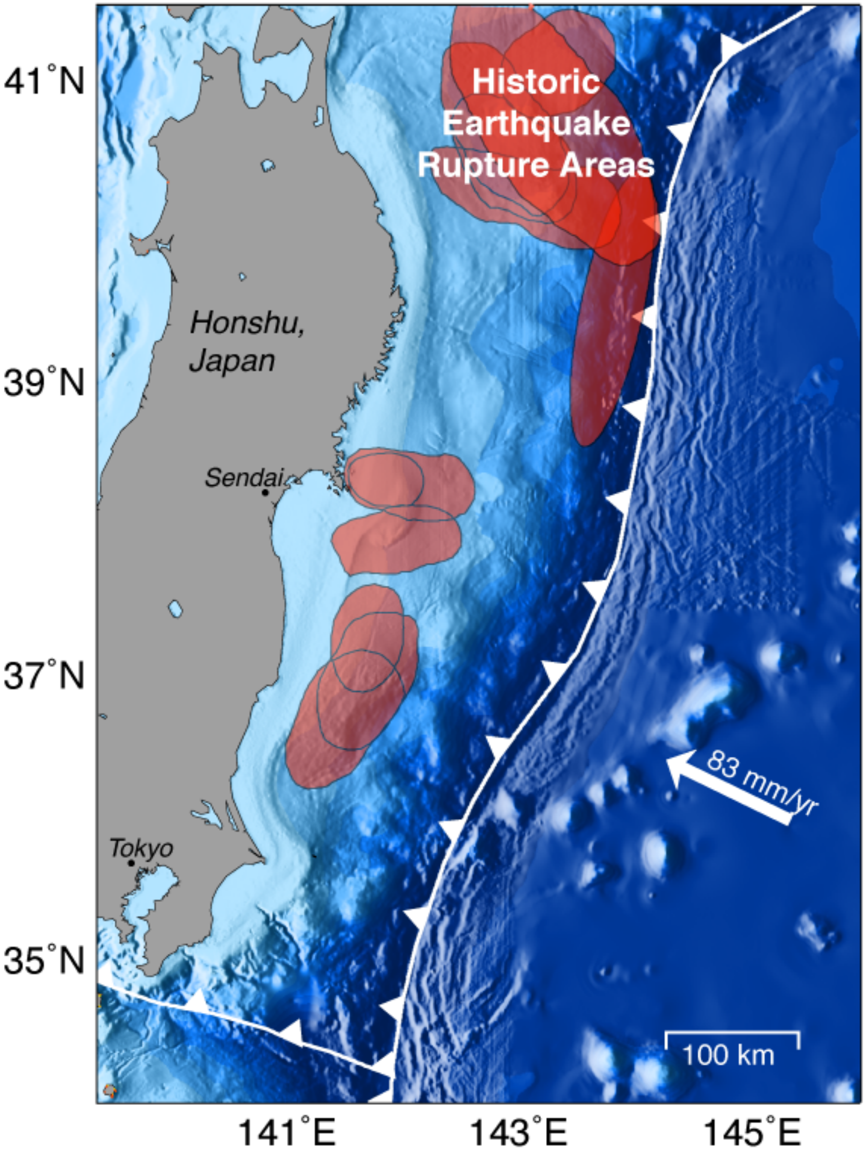
LARGEST THRUST EARTHQUAKE known as of 2010



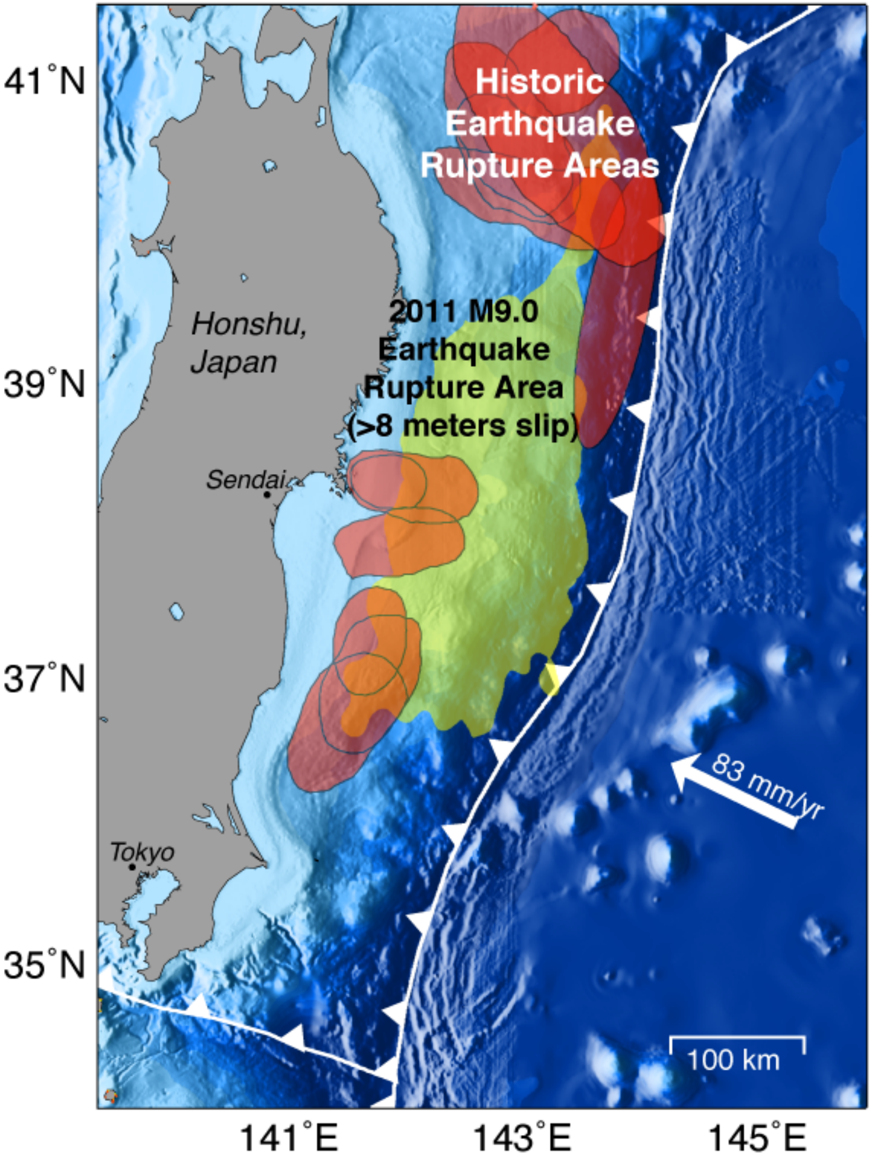
LARGEST THRUST EARTHQUAKE known as of April 2011



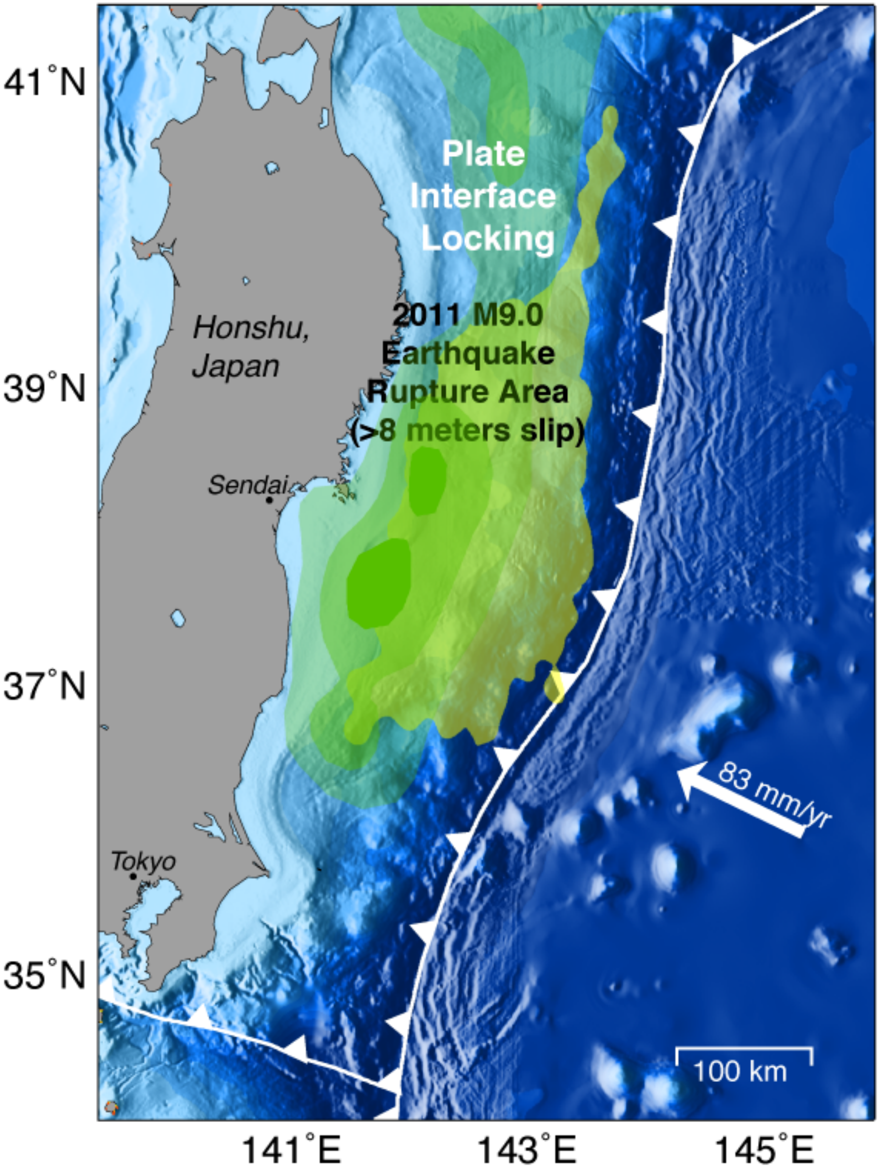
M9.0 - A Surprise



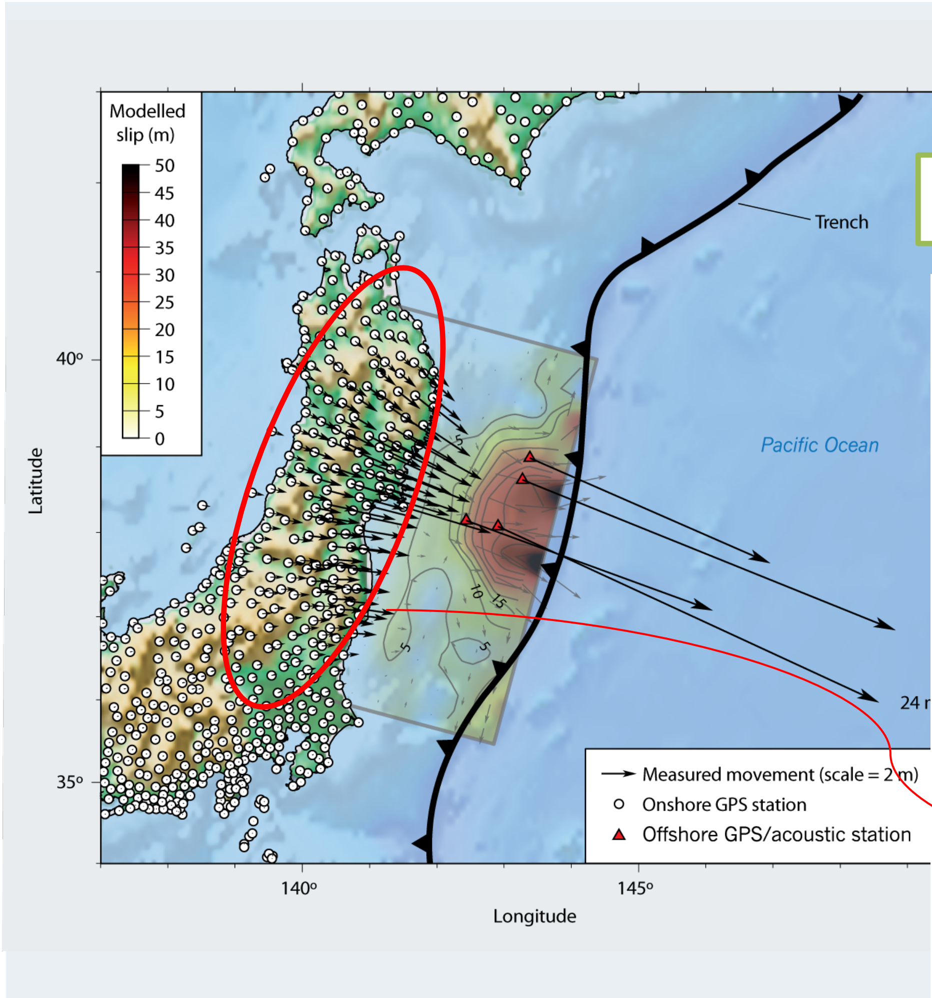
The Historic Record Too Short


41°N
39°N
37°N
35°N
141°E
143°E
145°E
Historic Earthquake Rupture Areas
2011 M9.0 Earthquake Rupture Area (>8 meters slip)
Honshu, Japan
Sendai
Tokyo
83 mm/yr
100 km

We are rethinking ideas about locking.

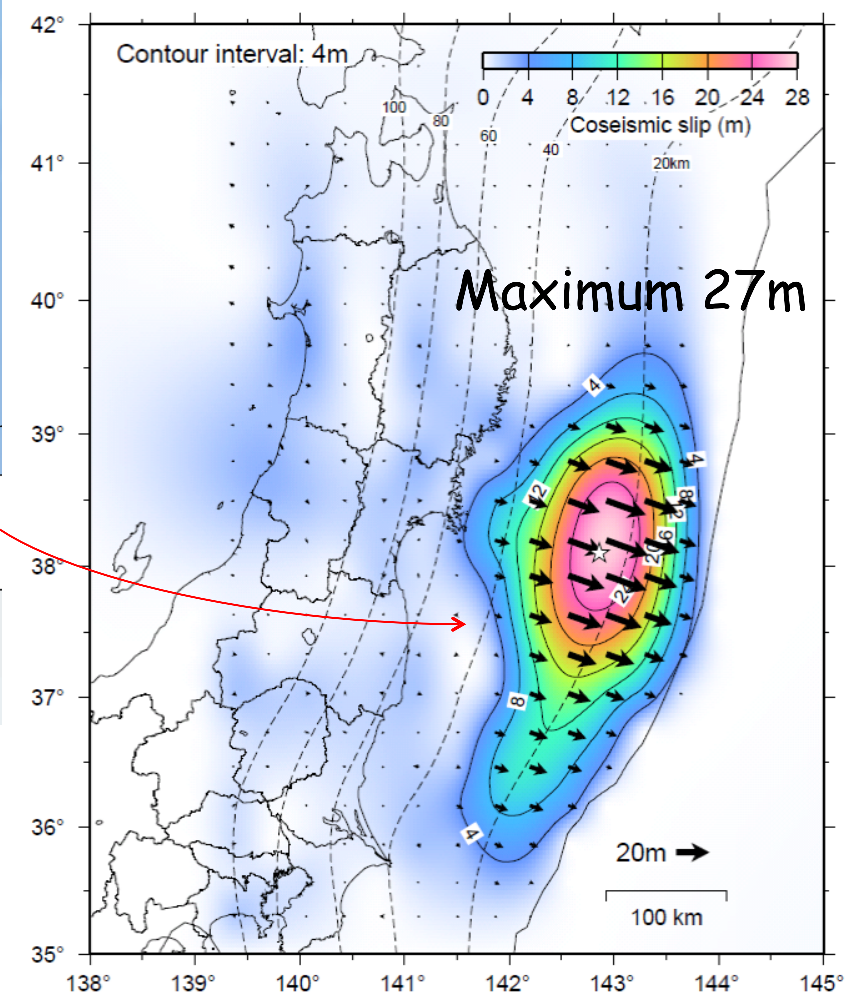


Offshore measurements are key.



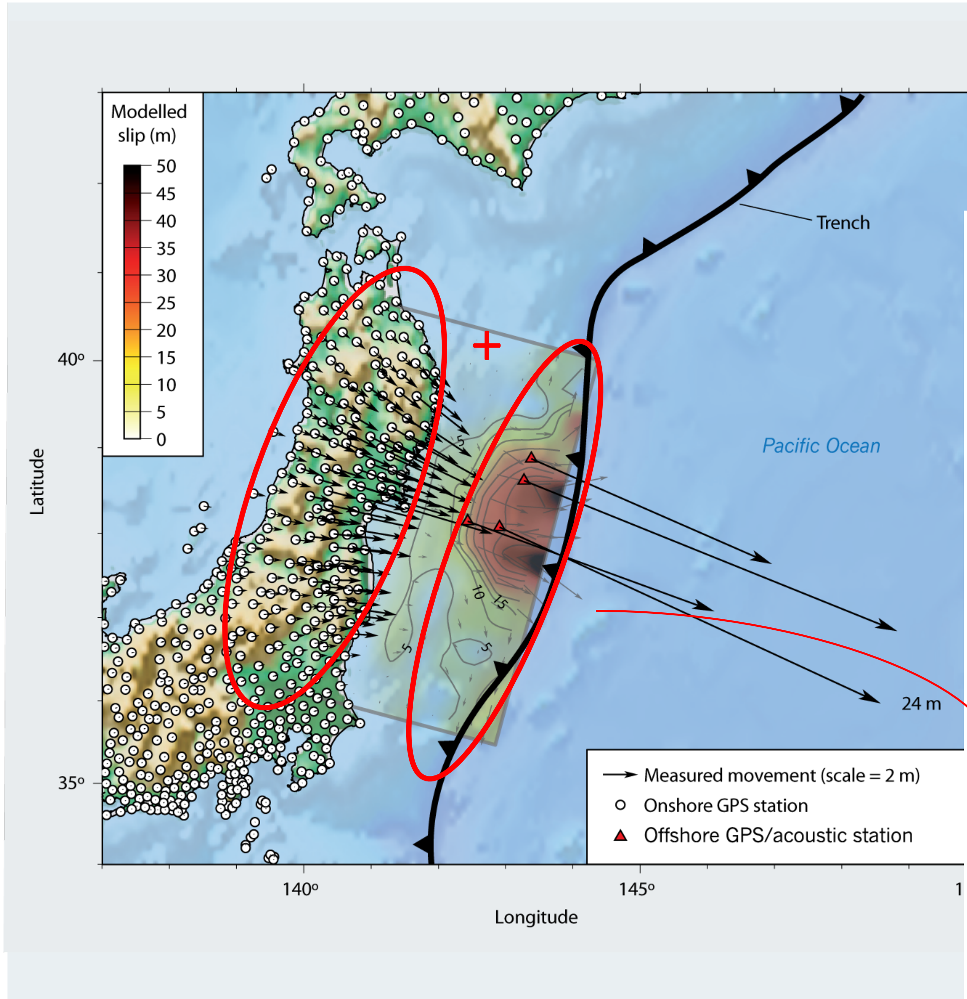
(Ozawa et al., Nature 2011)

Estimated by terrestrial GPS data only

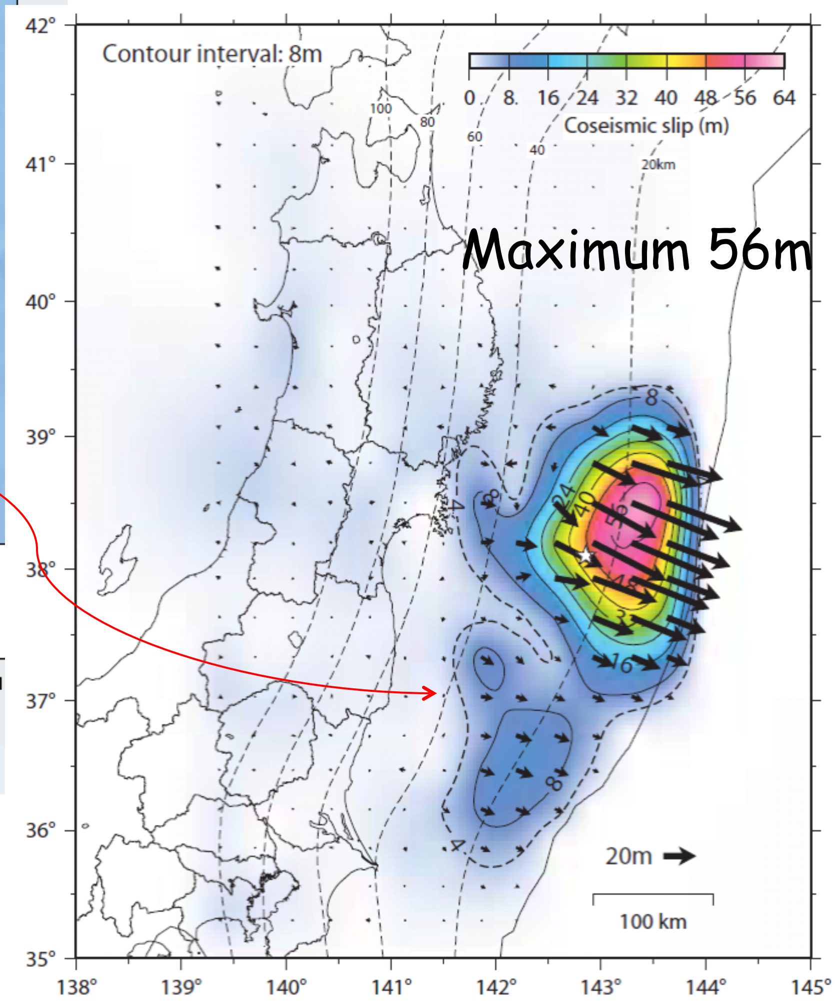


Maximum 27m

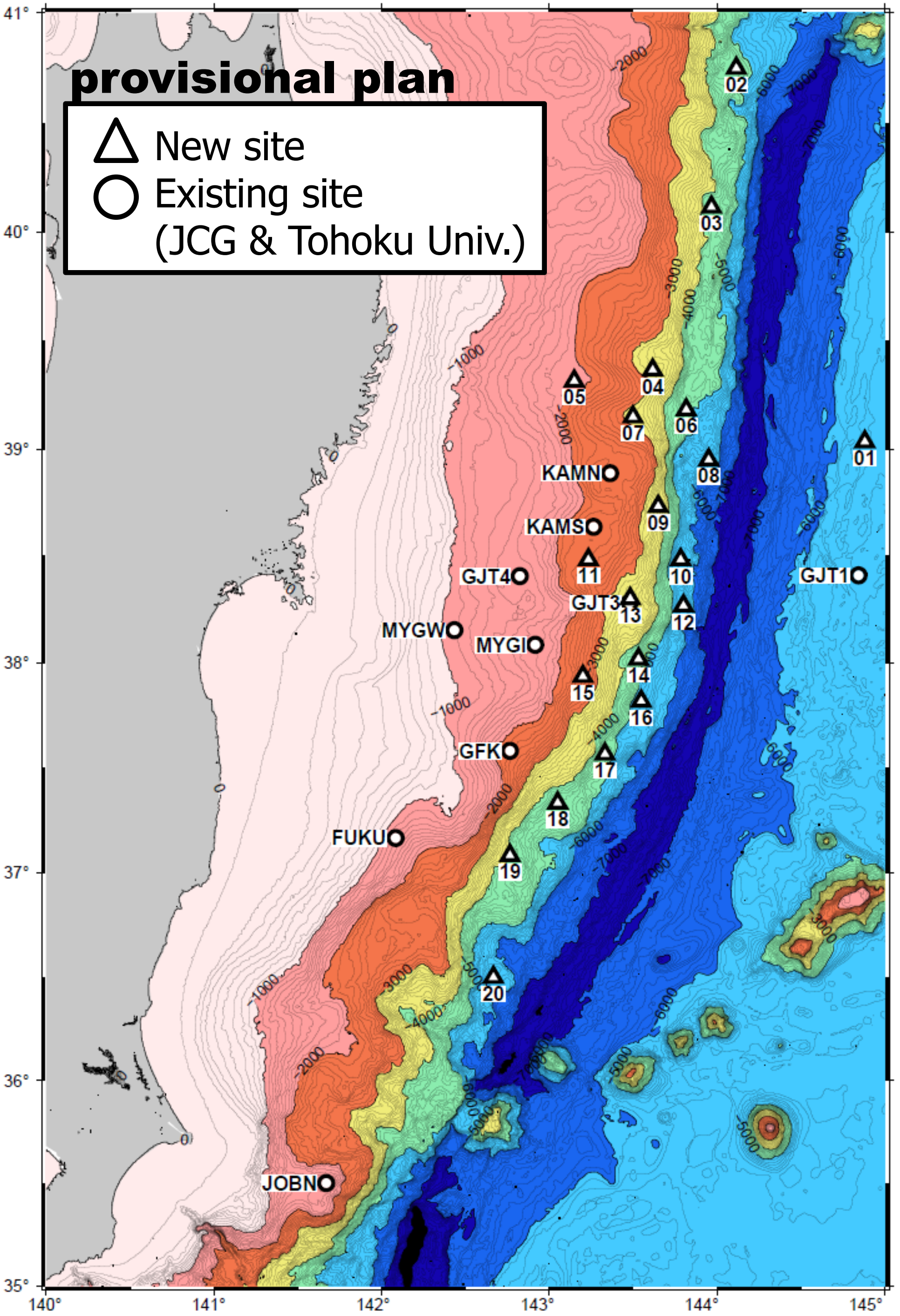
Offshore measurements are key.



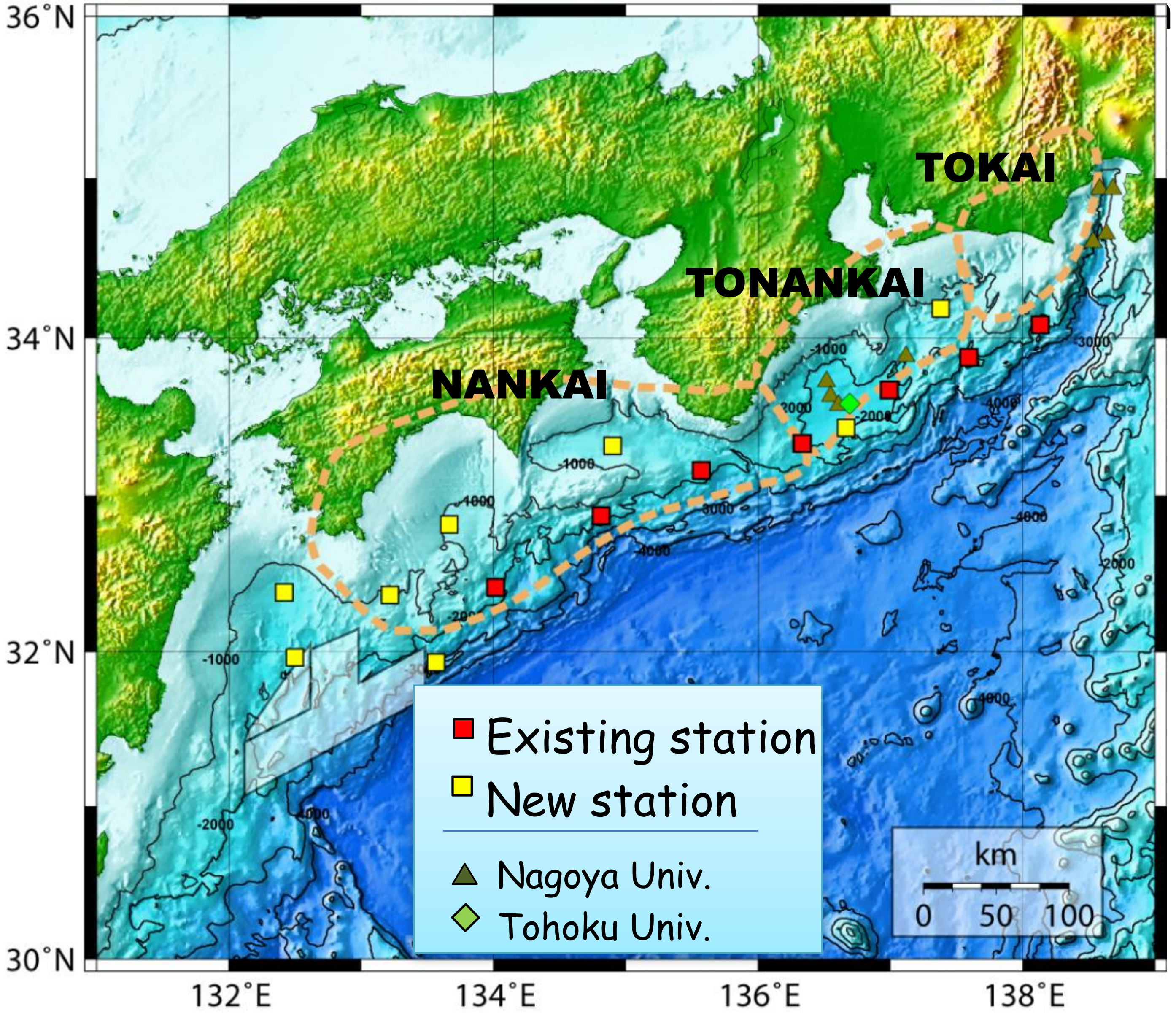
Estimated by terrestrial GPS data and seafloor GPS/Acoustic data



New investment in offshore GPS in Tohoku region.



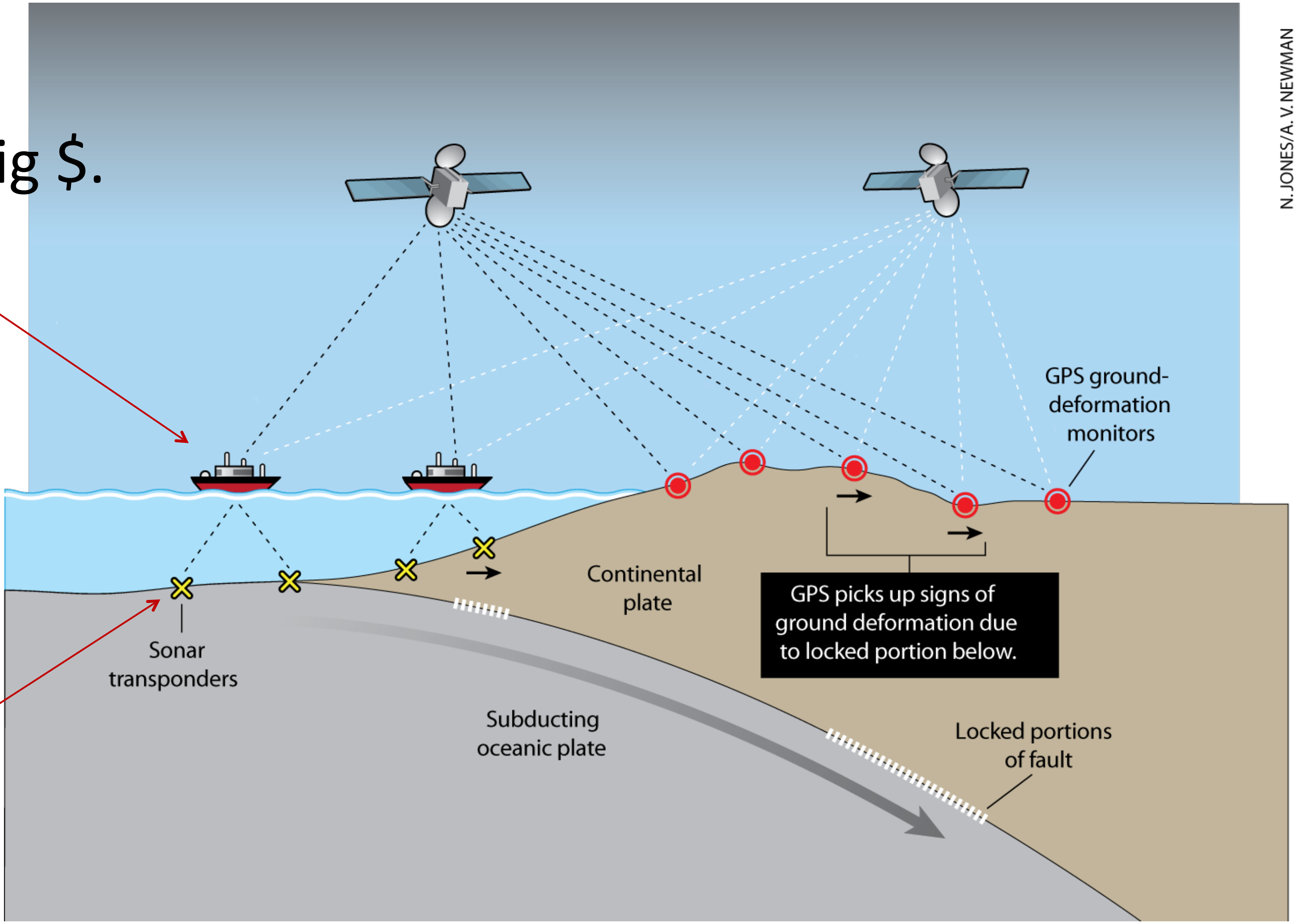
New investment in offshore GPS throughout Japan.



Offshore GPS is a new frontier.

Big ships = Big $.

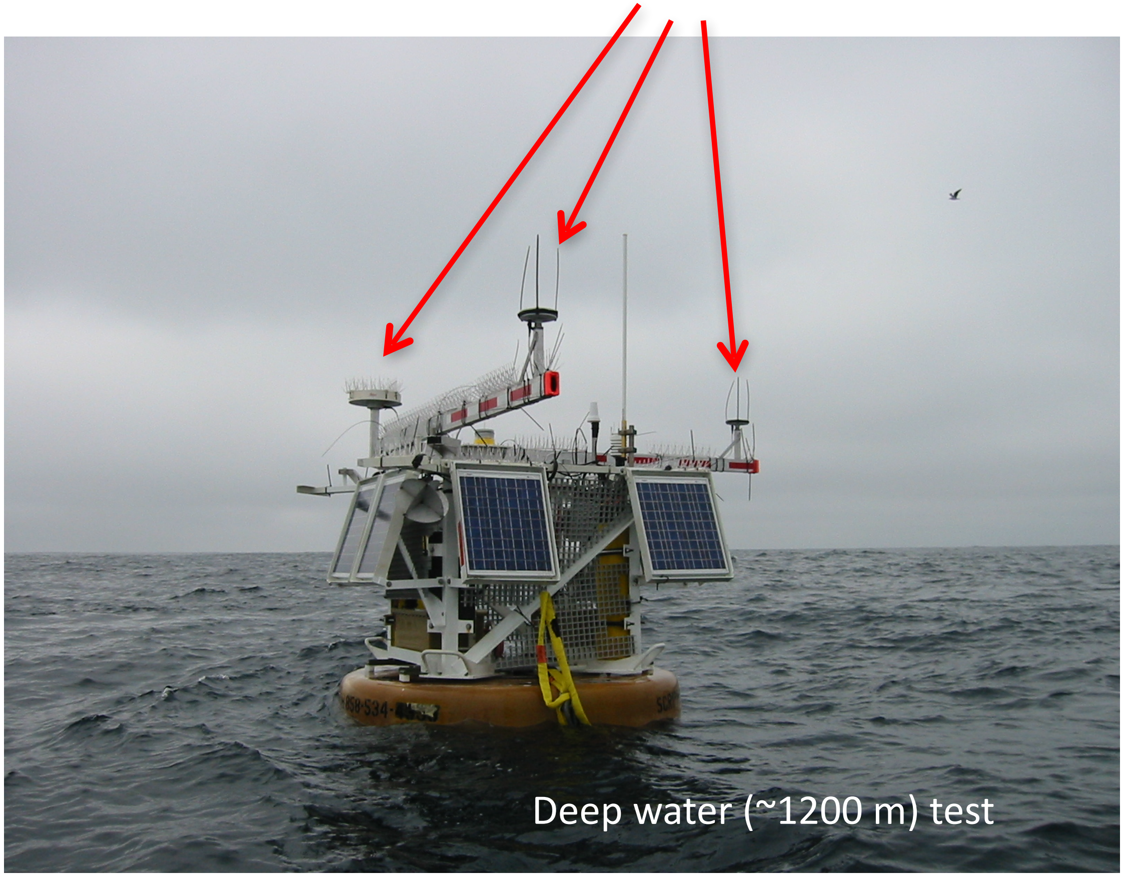
Stable markers on the seafloor difficult to plant & costly.


GPS ground-deformation monitors
Continental plate
GPS picks up signs of ground deformation due to locked portion below.
Sonar transponders
Subducting oceanic plate
Locked portions of fault

N.JONES/A. V.NEWMAN

Alternative 1: Autonomous, moored buoys

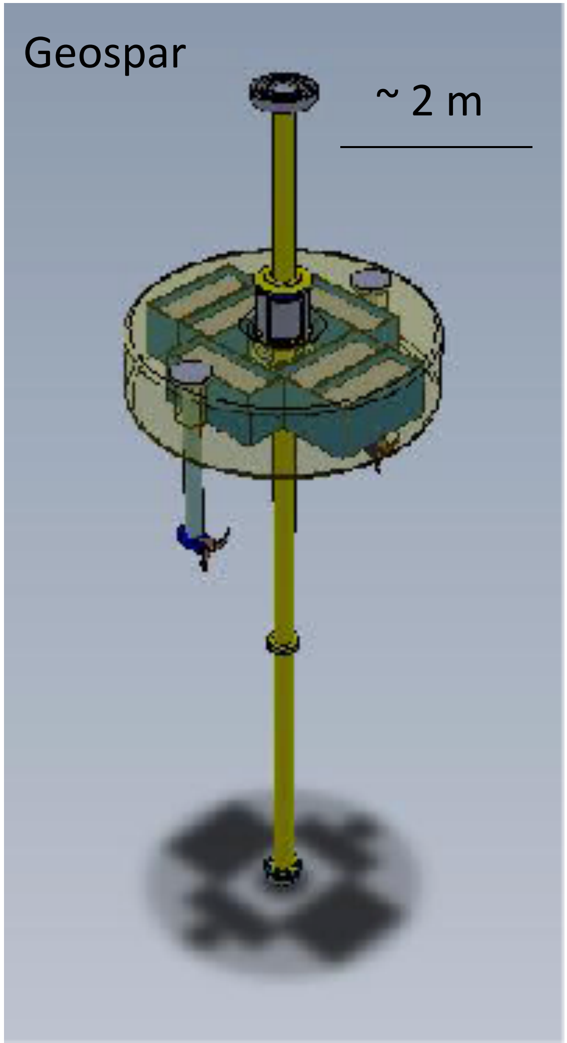
Increase the temporal resolution from months, years to days.



GPS antenna mounts

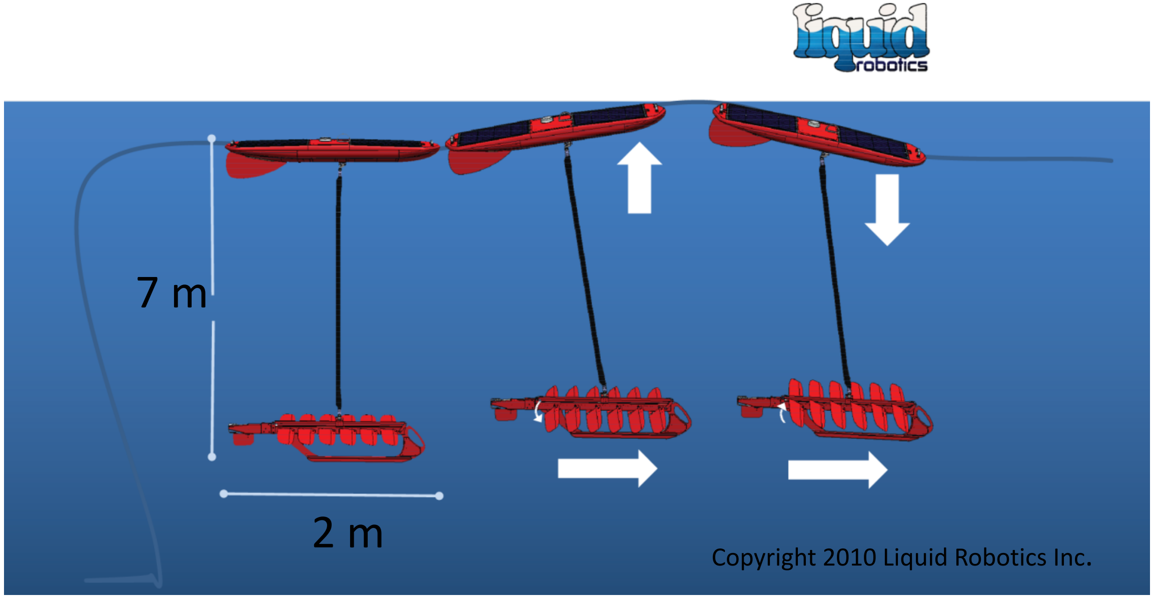
Deep water (~1200 m) test

Alternative 2: Mobile vehicles



Portable, Self-powered Float

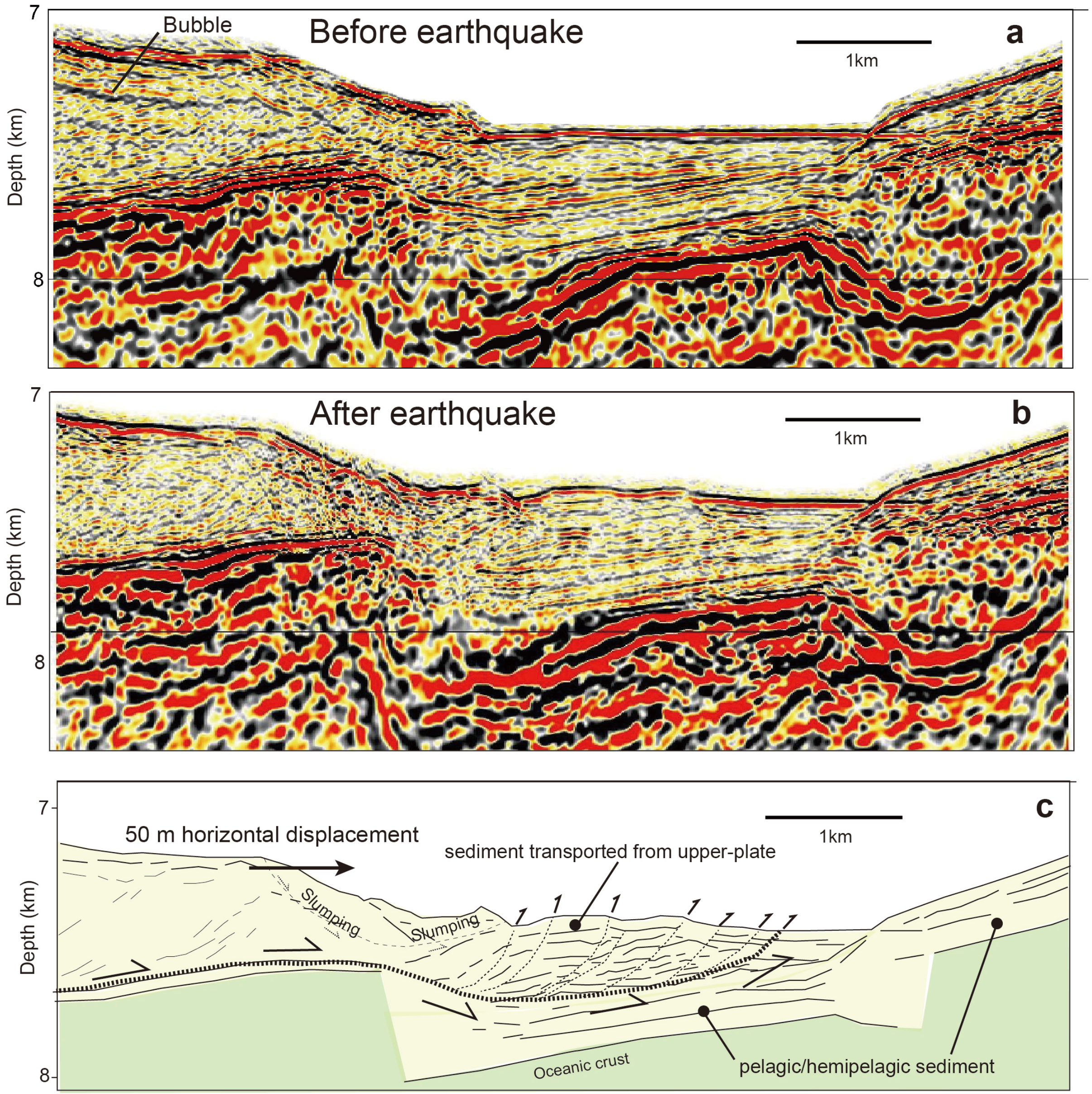
(deployable from small vessels)



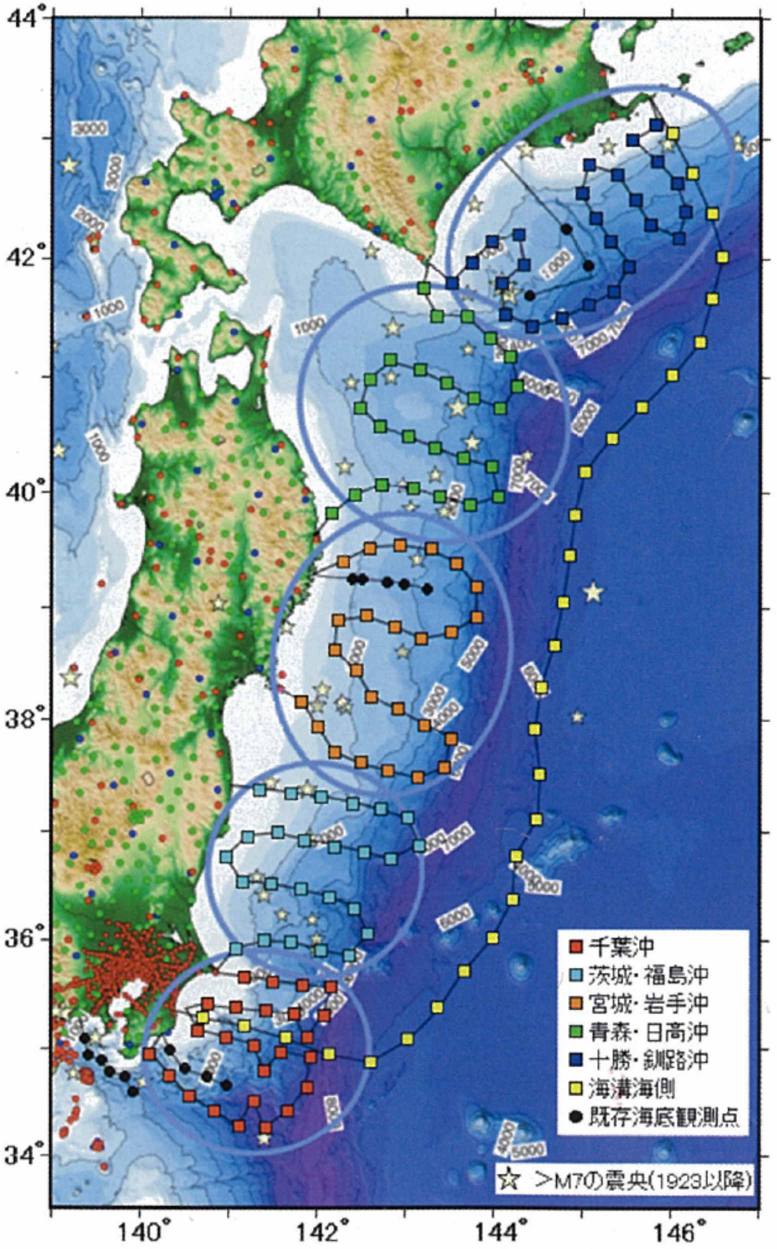
Copyright 2010 Liquid Robotics Inc.

Wave Glider

An earthquake ‘ultrasound’ helps to understand tsunami generation.



New investment in ‘before’ images.



Finally, a short movie about another surprise.